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NINTH QUARTERLY PROGRESS REPORT FOR THE APPLICATIONS TECHNOLOGY SATELLITE GRAVITY GRADIENT STABILIZATION SYSTEM

1 July Through 31 October

CONTRACT NO. NAS 5-9042

FOR THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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ABSTRACT

The ATS Math Model Computer Program was checked out on NASA/GSFC computers. Runs were made on both GSFC and GE computers and results agreed to better than 1%, which is considered sufficient evidence that no problems will be encountered because of difference in computers.

Computations of the ATS vehicle altitude dynamics has been obtained for several specialized maneuvers including the effects of the essential flexible characteristics of the rods. The maneuvers which have been investigated and which are detailed in Section 2.3 are Pitch Displacement and Thermal Twang.

The major contributor to boom deflection in orbit is the thermal bending component. An empirical and an analytical approach which have been investigated for determining the magnitude of rod bending are described in Section 2.4. The empirical approach assumes a good knowledge of rod material, optical properties, and radiant heat flux, and the analytical method assumes an intuitive approach to the problem.

The computer processing system to be used for evaluation of the ATS-A and determination of attitude has been completely specified. The modular systems of this computer program are illustrated in Figure 2-6.

Final performance estimates for the ATS-A and ATS-D are presented in Section 2.6. The estimates for the ATS-D consider performance both with stationkeeping and without stationkeeping.

The planned qualification program for the prototype primary and damper boom system was completed during the reporting period. A detailed summary of these tests and interpretation of results is given in Section 3.

A major problem was discovered during CPD Qualification testing. The eddy-current torsional restraint magnet mounting brackets failed during the second qualification-level vibration test. Detailed analyses of the failure resulted in a design change which was incorporated into the flight equipment. Discussions of prototype qualification and flight unit acceptance testing are included in Section 4.

The CPD for Flight A successfully completed the acceptance test and was shipped to the spacecraft contractor's plant. Life tests were continued on two of the engineering unit TV cameras (S/N5101 and 5102). TV camera S/N 5101 has accumulated over 2500 hours of operation and camera 5102 has accumulated over 1600 hours. The third engineering unit camera (S/N 5103) was used to obtain photographic data on TV target positions. Component qualification testing using the prototype cameras has been completed. The first two cameras that comprise Flight A (S/N 5107 and 5110) passed the acceptance tests. These units have been shipped to the spacecraft contractor's plant.

A Solar Aspect Sensor system, which is similar to the one used on the ATS vehicles is incorporated in the Air Force GGTS. As evidenced by actual flight data, the system operates properly except in the transition area of the two detector heads. This transition is analyzed in Section 5.2 for its effect in the ATS attitude sensing system. A method of curve fitting is recommended for these transition periods which will produce meaningful information from otherwise ambiguous data.

System compatibility testing of the prototype PCU at the spacecraft contractor's plant indicated that the transient current pulse which was generated when the unregulated power switch was energized was sufficient to immediately trip the switch. The problem was eliminated by the insertion of a capacitor ahead of the squib driver output stage in the PCU.

The first flight unit PCU was delivered to the spacecraft contractor in October. Acceptance testing of Flight Units 2 and 3 were completed toward the end of the reporting period, and the units were being prepared for bonded storage at GE for delivery at a later date.

The ATS Parts Qual Program was completed during the reporting period. All tests in the component qualification program were completed with the exception of the primary booms.

SECTION 1
INTRODUCTION

1.1 PURPOSE

This report documents the technical progress made during the period from 1 July to 31 October 1966 toward the design and development of Gravity Gradient Stabilization Systems for the Applications Technology Satellites.

1.2 PROGRAM CONTRACT SCOPE

Under Contract NAS 5-9042, the Spacecraft Department of the General Electric Company has been contracted to provide Gravity Gradient Stabilization Systems for three Applications Technology Satellites: one to be orbited at 6000 nautical miles (ATS-A), and two to be orbited at synchronous altitude (ATS-D and ATS-E). Each system will consist of primary booms, damper boom, damper, attitude sensors and the power conditioning unit. In addition to the flight systems, GE will provide a thermal model, a dynamic model, an engineering unit and two prototype units. GE will also supply two sets of aerospace ground equipment.

SECTION 2

SYSTEMS ANALYSIS AND INTEGRATION

2.1 EVENT SUMMARY

Events of significance to systems analysis and integration activities from July through September 1966 are summarized as follows:

7 July	"Rod Error Tradeoff Curves", PIR 41M1-162, was issued to assist in tradeoffs relative to deviations from primary boom system specifications.
8 July	"ATS Attitude Determination Investigation Program ADIP III Influence of the Weights on the Calculated Attitude Angles", PIR 4411-003, was issued. Subsequent evaluation culminated in a plan to weight POLANG to zero except in the vicinity of sun vector/earth vector coincidence and to weight all sensors to unity when in use.
11 July	Thermal bending tests on GE-instrumented boom samples were initiated at NASA/GSFC. Test specimens included a stainless steel, seamless "control" rod and a BeCu, overlapped rod. Temperature and deflection measurements were subsequently obtained in separate tests.
15 July	SVS-7429, ATS Data Formats Specification, was issued through GE Print Control and Reproduction.
19 July	Revision A of SVS-7312, ATS System Requirements Specification, was issued through GE Print Control and Reproduction.
28 July	"Description of the ATS Ephemeris Tape" issued by NASA/GSFC. This document contains the tape format for transmittal of POLANG data to GE; GE will be required to merge this data with that from the NASA Raw Telemetry Data Tape (RTDT) for processing of ATS attitude data.
29 July	"Abridged Attitude Equations for the Applications Technology Satellite" (containing only those equations pertinent to the ATS Mathematical Model) was published.

2-3 August	CCN negotiations at NASA/GSFC.
3 August	Received thermal bending data from tests conducted at NASA/GSFC.
8 August	Programming of gravity-gradient rod stiffness matrix program initiated.
12 August	Debugging of fixed-geometry portion of boom dynamics program completed.
19 August	"ATS Sun Sensors: Measurement Errors and Weights", PIR 4411-007, was issued. Maximum angular error in sun direction, for 1 count error in sensor output data, was found to vary from 0.66 to 0.83 degrees with the latter value occurring at only 1 point in the useful field of view of 1 sensor.
23 August	ATS-D capture studies, using the ATS Math Model, confirm the necessity of primary boom deployment within 30 degrees of the local vertical for an initial (prior to boom deployment) pitch rate of 0.80 ± 1.2 deg/sec.
24 August	Checkout of the ATS Math Model on NASA/GSFC computers was initiated.
24-26 August	TV pictures of simulated boom tip targets were obtained for checkout of TVCS data reduction techniques.
1-2 September	GE presented a 2-day lecture series on the ATS Gravity-Gradient Stabilization System to a group of systems engineers at NASA/GSFC. These engineers will be assigned supervisory responsibilities at the ATS ground stations for the duration of the operational phase of ATS. The lectures are summarized in Document No. 66SD2032; GE's participation was part of a 6 week ATS Systems Engineers Training Program sponsored by NASA/GSFC.
2 September	Checkout of the ATS Math Model on GSFC computers was completed.
14 September	"ATS Attitude Determination With Two Reference Vectors", PIR 4411-009 was issued. This analysis pertains directly to the quick-look attitude determination program as well as first trial solution in the long-term data analysis.
20 September	"Experimental Verification Studies of Thermal Bending Theory for deHavilland Type Gravity-Gradient Rods", Experiment Technology Data Report 2-66, was issued. This report summarized results to date of GE/ATS thermal bending tests at NASA/GSFC.

27 September	Final design completion performance estimate for ATS-A and ATS-D/E issued as PIR's 41M1-254 and 41M1-253.
28 September	NASA program review at GE.
29 September	Debugging of variable geometry portion of boom dynamics program completed. Program now ready for evaluation of boom dynamics response and feedback to rod extension/retraction maneuvers, scissoring, thruster inversion and thermal twang.
3 October	Continuation of NASA program review at GSFC.
6 October	Installation geometry for ATS-A primary boom system flight tapes specified; specification was based on analysis to minimize errors due to out-of-spec initial straightness data.
10 October	"ATS Data Reduction Computer Software System Description" published as PIR 4A26-096. This document provides a detailed description of the Data Reduction Module (DRM) and its interfaces with the Data Analysis Module (DAM).
12 October	An ATS prototype hardware telemetry data calibration book was assembled for publication. This book is organized by telemetry function and was generated, primarily, for use in programming the Data Reduction Module of the Attitude Determination Program. The data is considered representative of ultimate flight hardware data in the sense that only minor corrections to the DRM will be necessitated by receipt of actual flight hardware data. Only missing data at time of publication is that required from NASA/GSFC.
19 October	NASA/GSFC decision to shift control of the quick-look data system interface (NASCOM/DATANET 30) from ATSOCC to GE/STC. NASA new proposes to install a "full duplex line to GE, terminating in a TWX machine with punched paper tape capability." Definition of the remainder of the system is being formalized for forthcoming negotiations.
24 October	GE initiated preparations for Data System Checkout (Work Package 2150) which is scheduled to commence with completion of the Data Reduction Module on December 1.

2.2 ATS MATHEMATICAL MODEL

2.2.1 CHECKOUT STATUS

The ATS Math Model computer program has completed checkout on NASA/GSFC computers. The following runs were made on both GSFC and GE computers with correlation better than 1% in all cases:

a. Constant pitch torque (no disturbances)

b. Constant roll torque (no disturbances)

c. Constant yaw torque (no disturbances)

d. Sinusoidal pitch torque (no disturbances)

e. Sinusoidal roll torque (no disturbances)

f. Sinusoidal yaw torque (no disturbances)

g. Solar torque disturbances

h. Thermal bending

Correlation was also obtained on orbit and magnetic field parameters.

The above runs and the resultant close agreement between results on the GSFC computers and the GE computer is considered sufficient evidence that no problems will be encountered due to differences in computers. Engineering checkout of the Math Model has also been completed. Corrections to the NASA deck and listing, to update to the status of the GE deck, are being documented for early shipment to GSFC.

2.2.2 DELIVERY STATUS

Documentation of corrections to the NASA Math Model deck and listing will be forwarded to GSFC in the near future. Subsequently, the Math Model User's Manual will be completed and delivered; with delivery of the manual, Math Model delivery will be considered an accomplished fact.

For a period of one year following delivery, GE has agreed to notify NASA/GSFC of any changes required in NASA's deck to ensure correctness of output.

2.3 BOOM DYNAMICS STUDIES

References: 1. Roach, R. E., "Equations of Motion for a Flexible Body in Space," PIR 4145d-343, Revision A, 27 July 1966.

2. Roach, R. E., "Motion of Rod End Mass Relative to Center Body Rotation," PIR 4145-223, Revision A, 29 November 1965.

2.3.1 INTRODUCTION AND SUMMARY

Computations of the ATS satellite (Figure 2-1) attitude dynamics, including the effects of the essential flexible characteristics of the rods, have been obtained for several specialized maneuvers. The equations of motion for a flexible body in space, developed in Reference 1, were used for this investigation. The general equations were reduced to a circular orbit case in order to limit the number of variables. The method of evaluation of these equations is the GE DYNASAR(*) program.

The maneuvers which have been investigated to date are:

a. Pitch Displacement
b. Thermal "Twang"

The pitch displacement maneuver consists of a torque pulse about the center body, with all booms in their extended positions. Thermal "twang" is simulated by considering the rods in an initial deflected position. Initial deflections were selected in order to produce a more violent condition than would be expected in the actual flight environment.

The satellite representation as programmed on DYNASAR can be used for various maneuvers and initial conditions.

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* DYNASAR - A digital computer program simulating the problem solving capabilities of the analog computer.

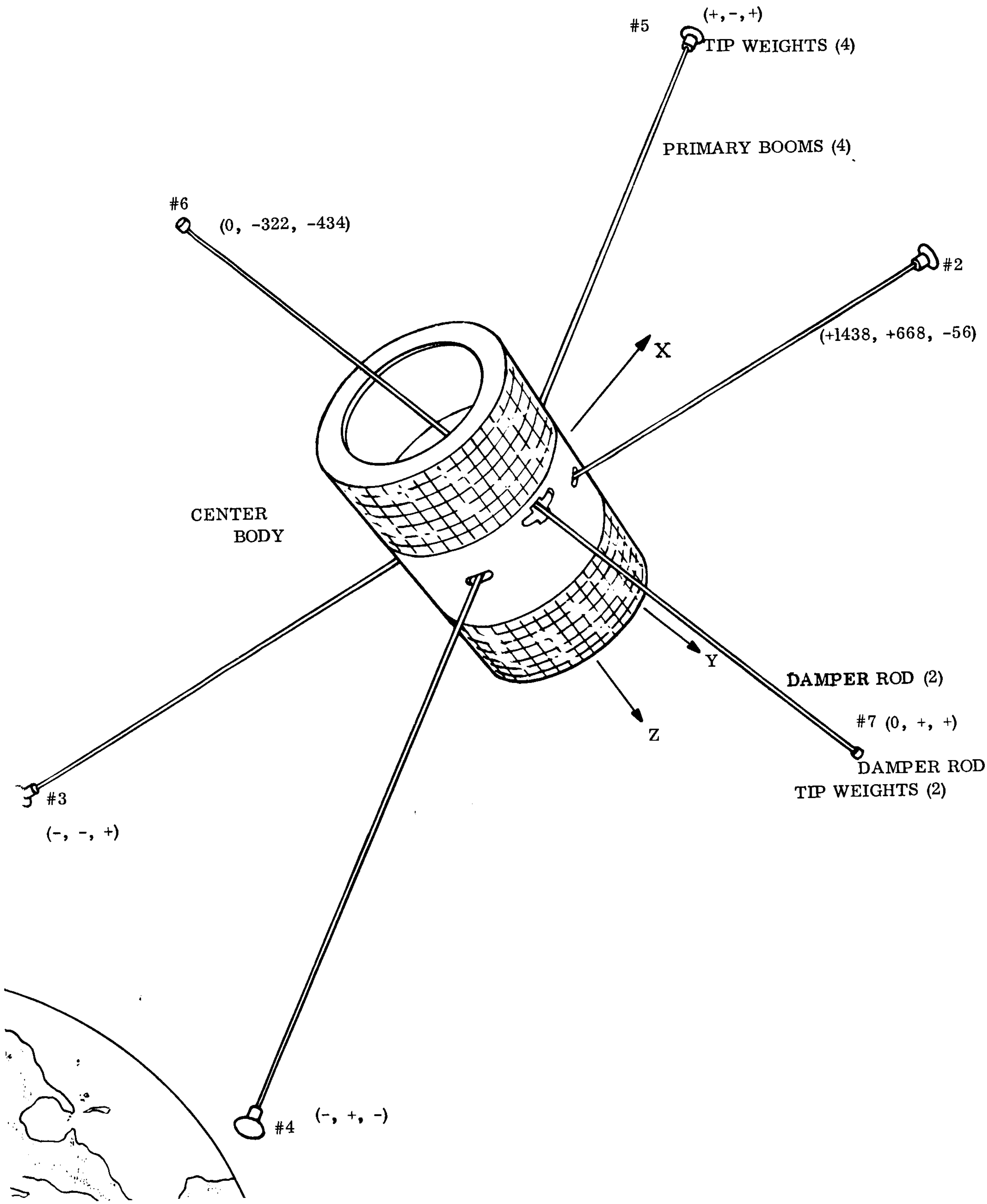


Figure 2-1. ATS Reference Frame

2.3.2 BASIC ASSUMPTIONS AND SIMPLIFICATIONS

The DYNASAR program can handle a maximum of 500 variables; because of this limitation, certain simplifications have been made regarding the spacecraft and its environment.

These are:

a. Equations are reduced to the circular orbit, spherical earth case; no other pertubations are considered.

b. Only mechanical forces are represented.

c. The vehicle is represented by 24 degrees of freedom, 21 translational coordinates (representing three components of translation for the center body and each of the rod end masses) and three center body rotational degrees of freedom.

d. Previous representations of the ATS vehicle consisted of 42 degrees of freedom and mode shapes. The present analysis has been reduced to 24 coordinates by the elimination of boom tip rotations. This reduction was necessary in order to fit the problem into the DYNASAR program. The nature of the force field (Equation 23 of Reference 1) indicates negligible admittance into these modes. The 20 lowest modes of the 42-mode analysis are presented in Reference 2. Agreement between these modes and the present analysis is close for the lowest 18 modes.

2.3.3 PITCH DISPLACEMENT

The mass-expulsion system used for the inversion maneuver was simulated by the application of a moment to the center body in the orbital plane. The applied forcing function consisted of a 0.015 in.-lb moment applied for 60 seconds and reduced to 0.005 in.-lb for 1140 seconds. The reduced moment was designed to simulate leakage rate from the thruster. System response was obtained for a total of 2000 seconds.

The angular response of the center body is shown in Figure 2-2. The maximum angular displacement in the orbital plane for this thrust profile is 0.17 radians at 1600 seconds (400 seconds after thruster cut-off). The magnitude of this displacement then decreases, indicating the start of a recapture sequence of the vehicle.

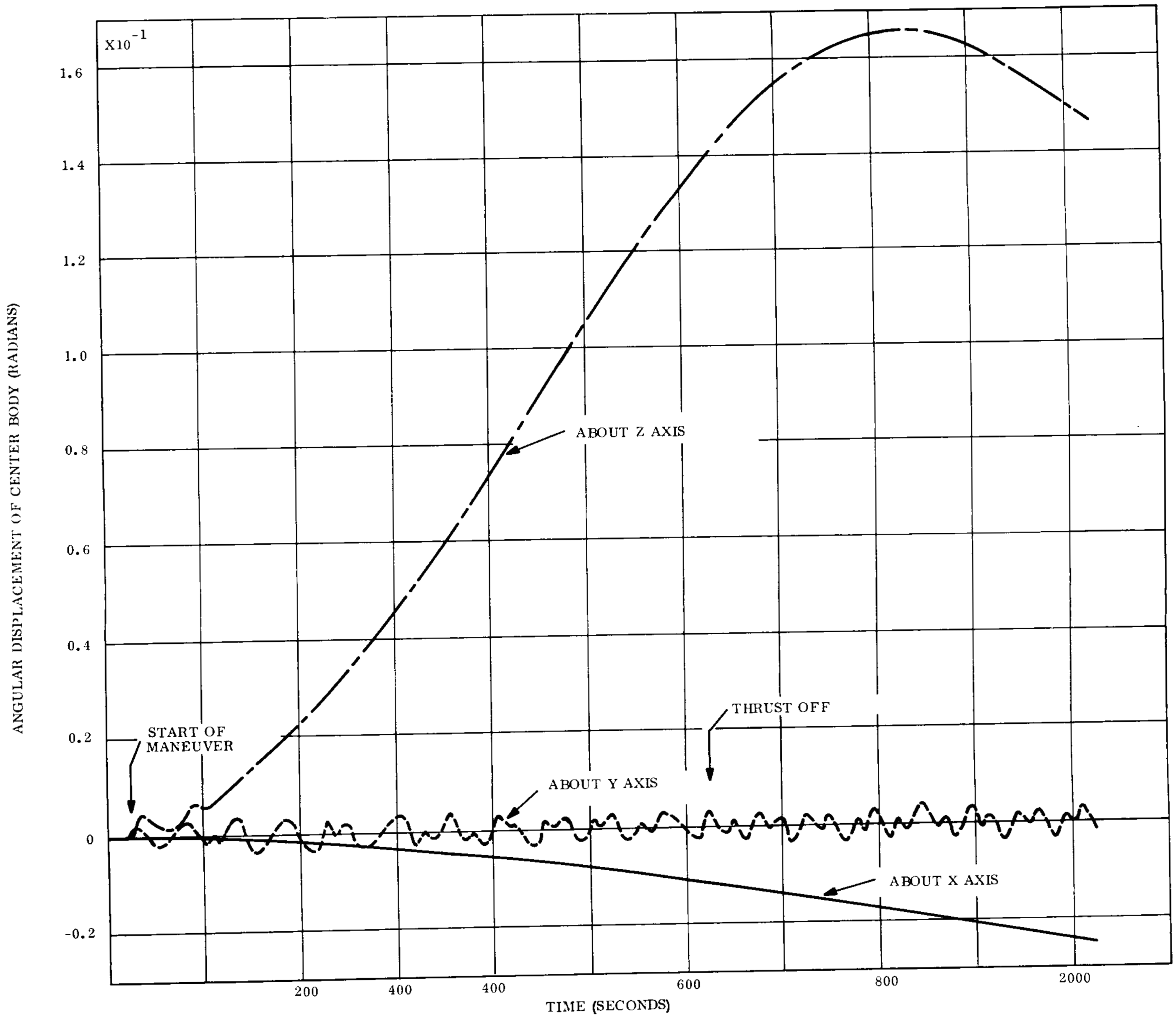


Figure 2-2. Center Body Rotations for Pitch Maneuver

The angular displacement of the center body about the Y axis is small and oscillatory, never exceeding $\pm 5 \times 10^{-3}$ radians.

The center body rotation about the X-axis is not completely understood. At 2000 seconds, the magnitude of this rotation is -0.024 radians, and is increasing. It is projected that this rotation is a consequence of the system representation of the attachment of the damper booms to the center body. The damper booms have been represented fixed to the center body (originally because of program size), hence there is no effect of damping from the relative motion between the damper booms and the center body. This representation is currently being re-investigated in detail.

2.3.3.1 DATA From Computation

Maximum primary boom tip displacements are as follows:

X direction	-	$\pm$ 0.34 in.
Y direction	-	$\pm$ 7.0 in.
Z direction	-	$\pm$ 6.0 in.

Maximum damper boom tip displacements are:

X	-	$\pm$ 1.0 in.
Y	-	$\pm$ 0.1 in.
Z	-	$\pm$ 0.08 in.

The forces produced by these motions are:

Primary booms	-	1.38×10^{-5} lb
Damper booms	-	5.0×10^{-5} lb

Maximum rod bending moments have been calculated as:

Primary boom - 2.19×10^{-2} in.-lb

Damper boom - 2.70×10^{-2} in.-lb

Rod forces and bending moments computed for the inversion maneuver do not exceed critical values (6 in.-lb is critical).

Center body rotation about the X-axis indicates a deficiency in modeling and is not considered representative vehicle behavior. This motion is being investigated further.

2.3.4 THERMAL "TWANG"

Thermal "twang" was simulated by placing the rods in initial deflected positions matching their sunlight positions when entering earth shadow. "Out of plane" bending was included by deflecting the damper booms out of the sun-rod plane. The effect of these particular initial conditions produces a more severe "twang" condition than would be anticipated in the normal flight environment.

For this run, the "twang" is input as a step rather than as a 40 second transition, as would be the case in the flight environment. Also, the effects of the penumbra have been neglected as the rods are considered to go directly from sunlight to umbra. Vehicle shadow patterns and coordinates are also not considered.

The initial rod deflections shown in Figure 2-3 are as follows:

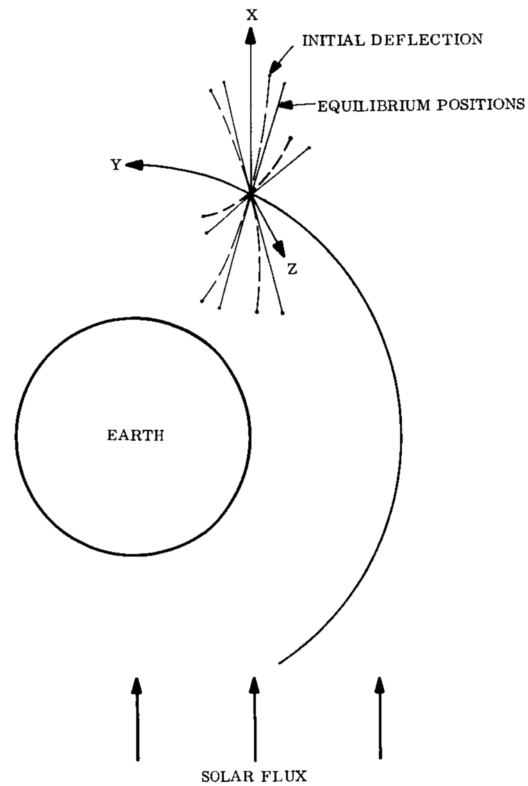


Figure 2-3. Initial Rod Deflection for Thermal Twang Computation

		Deflection in Inches		
		X	Y	Z
Primary booms	No. 2	0	11.5	0
	No. 3	0	11.5	0
	No. 4	0	19.0	0
	No. 5	0	19.0	0
Damper booms	No. 6	1.9	0	0
	No. 7	1.9	0	0

2.3.4.1 Results From Computation

The center body rotations are shown in Figure 2-4. For a 1000 second period, the angular displacements about the Y and Z axes are small, with maximum values as follows:

Y @ 1000 sec 1.3×10^{-4} radians

Z @ 175 sec 2.8×10^{-5} radians

The rotation about the Y axis is increasing at 1000 seconds. In order to more completely determine the behavior of this rotation a longer run will be necessary.

Rotation about the X-ray exhibits behavior identical to the inversion case, which reinforces the tentative conclusions discussed there.

Typical primary boom tip motion is shown in Figure 2-5. The displacements shown are for rod No. 2 in the X, Y, and Z directions. The initial deflected position of this boom is 11.5 inches in the Y direction. The maximum deflections for this boom are:

X - $\pm$ 4.0 inches

Y - + 11.5 in., -9.5 in.

Z - $\pm$ 0.5 inches

For the primary booms with initial deflections of 19.0 inches, the maximum displacements are:

X - $\pm$ 7 in.

Y - $\pm$ 19.0 in., -17.0 in.

Z - $\pm$ 0.28 in.

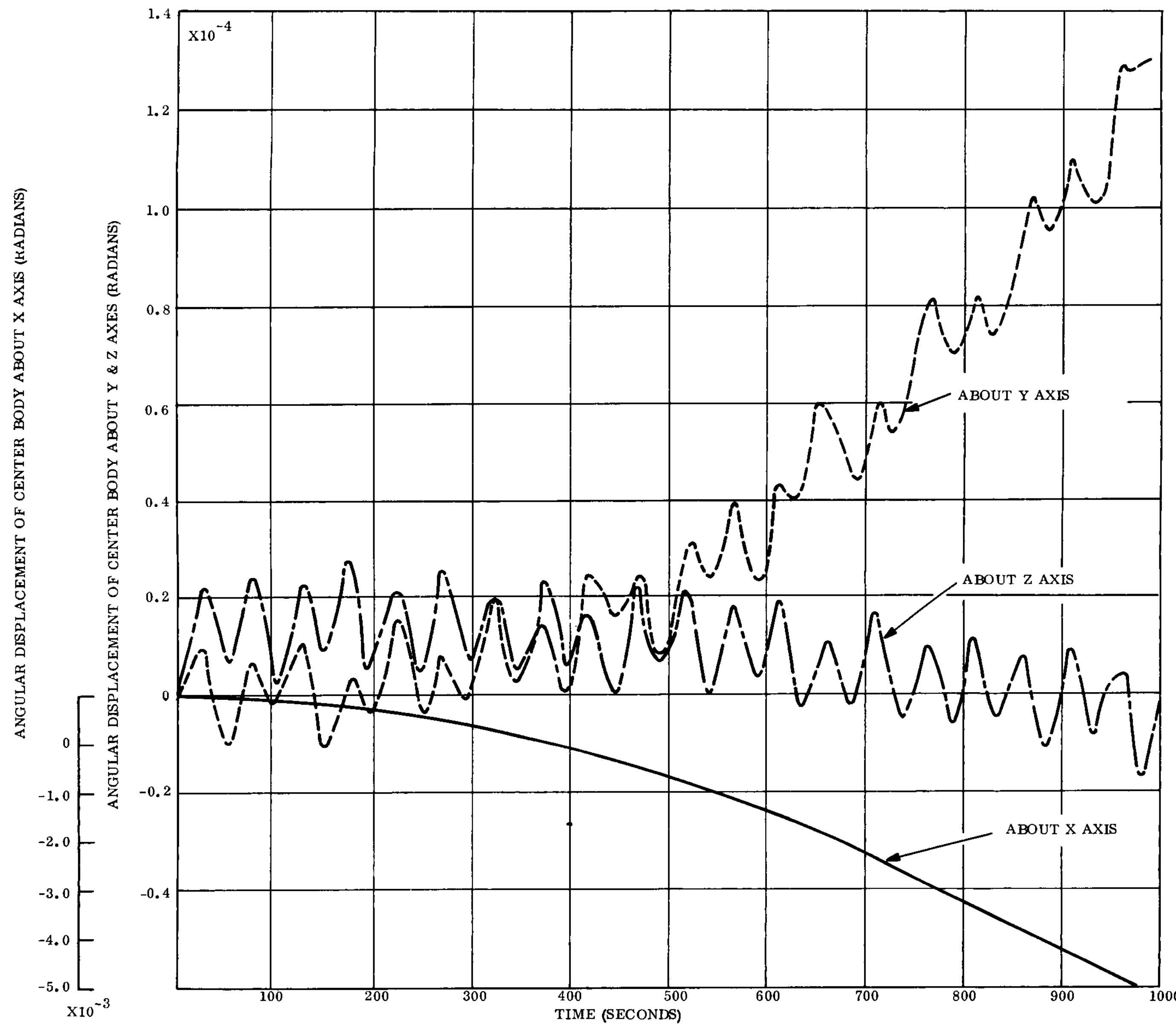


Figure 2-4. Center Body Rotation for Thermal Twang

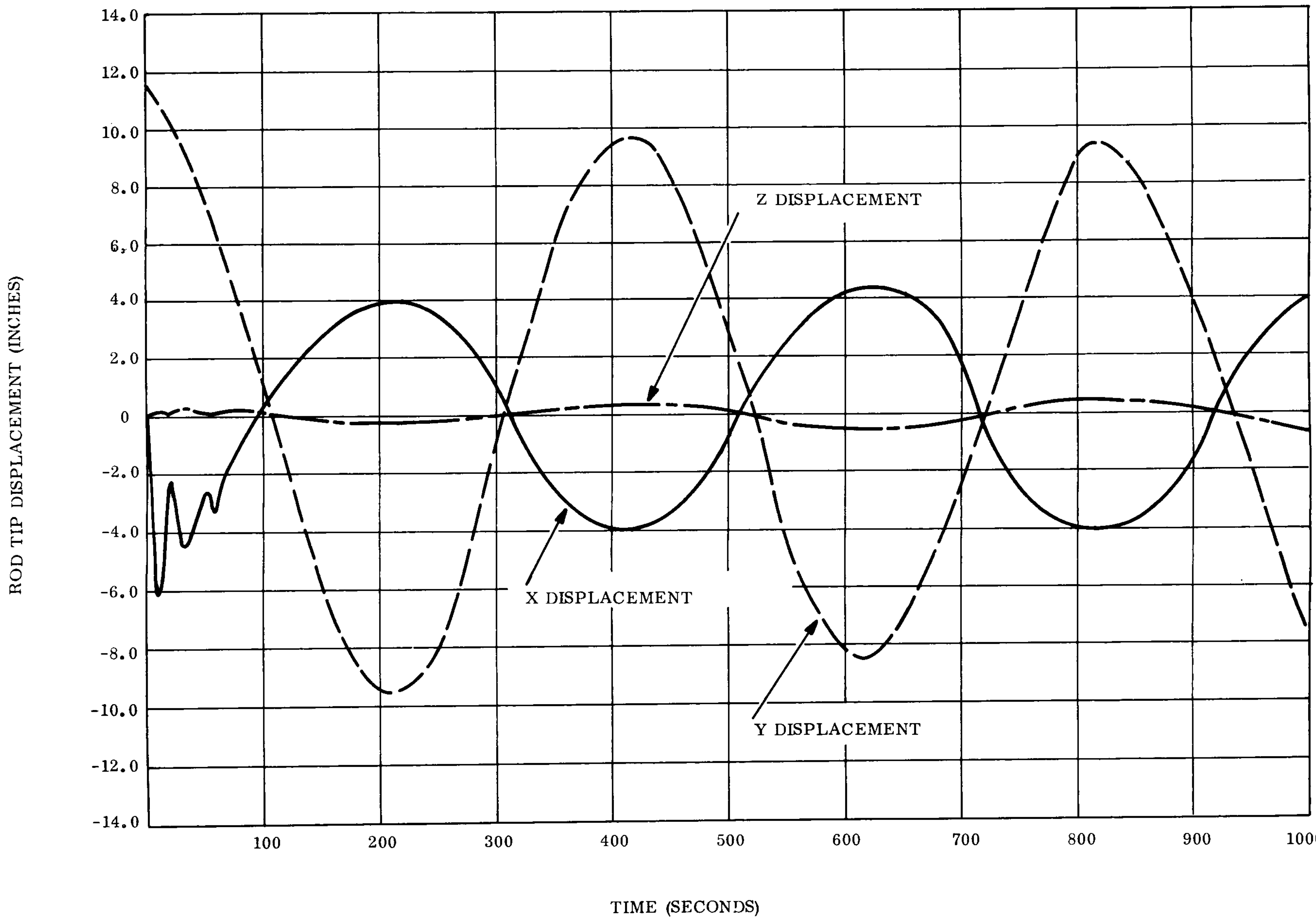


Figure 2-5. Typical Primary Boom Tip Motion for Thermal Twang

Maximum damper boom deflections are:

X + 1.9 in., -1.0 in.

Y $\pm$ 1.1 in.

Z $\pm$ 0.77 in.

The maximum rod forces and bending moments due to these motions occur in primary booms No. 4 and No. 5 and are:

Maximum force - 2.55×10^{-5} lb

Moment - 4.03×10^{-2} in.-lb

These values are less than the critical values for these booms.

Center body rotations due to the thermal "twang" computation do not approach significant values, but will be rechecked for a longer response time.

2.3.5 VARIABLE GEOMETRY ANALYSIS

the DYNASAR setup described in the previous section has been modified to allow for variable vehicle geometry in order to simulate rod extension and scissoring for initial capture.

In order to fit the capture sequence (variable geometry) into DYNASAR, a further simplification was necessary. In the variable geometry setup, field forces act only through the rigid body coordinates and do not vary with elastic deflections of the rods. Results from a comparative calculation run with the fixed geometry setup for the inversion case, indicated agreement within 5% between the two setups.

2.4 BOOM THERMAL BENDING STUDIES

Flexible gravity gradient rods are represented in the ATS Math Model. Early investigation showed that the major contributor to rod deflection in orbit is the thermal bending component. The modeling of this effect is presented in Document No. 66SD4214, Attitude Equations for the Applications Technology Satellite, 1 June 1966. The position of the tip mass for each rod is represented by an equation of the following form:

$$Ax^2 + Bx + C = d$$

where

x = rod length

d = displacement of rod end

A, B, C are coefficients dependent upon rod properties, sun angle twist rate and rod geometry.

Studies to date indicate that the form of the equation is suitable and adequate for defining rod end position.

Two approaches are undertaken to determine proper numerical values for the coefficients of the above equation. They are an empirical approach and an analytic approach.

2.4.1 EMPIRICAL APPROACH

2.4.1.1 Ground Test

A series of carefully planned and executed tests on closed stainless steel tubes and bare BeCu, deHavilland-type gravity gradient rods are reported in GE Spacecraft Department Experimental Technology Data Report No. 2-66. The tests proved conclusively that the temperature distribution can be analytically predicted with good accuracy if the rod material, optical properties, and radiant heat flux are known. Unfortunately, the results of the deflection measurement portion of the tests proved inconclusive. The results have been carefully reviewed and several ideas have been put forth for obtaining improved deflection test data. None of the methods offer assurance, however, that the planer and out of plane components of rod bending can be accurately determined in this manner. For these reasons, increased emphasis is being placed on the orbital phase of testing.

2.4.2 ORBIT TEST

Flight data will be acquired by means of television cameras viewing tip targets mounted on the ends of each of the primary booms. Data sampling rates will be high enough so that six to ten points of data will be acquired in one fundamental period of the rod. All data will be time-correlated and computer programs provided so that sun-position/rod-plane definition is known. This data will provide the first real information on the behavior of long thin rods in an orbital space environment. Immediately available from this data will be vibration frequency, amplitude, and damping information. The vibratory component will be removed from the rod deflections yielding the deflected equilibrated rod end positions. By statistical processes, a mean displacement can be established which is independent of rod sun azimuth angle for specific sun rod incidence angles. The mean deflection thus obtained can be converted into a closed tube curvature which is the principal component of the coefficient "A" in the thermal bending equation. The mean curvature versus sun rod incidence can be used to verify the cosine relationship used for the temperature prediction. The acquired data will be further analyzed to establish its dependence upon rod sun azimuth angle. Variation of the mean displacement amplitude with sun azimuth angle, provides the ratio of the principal curvatures of an idealized rod and form, a second important contribution to the coefficient A. The disassociation of the mean displacement amplitude variation with sun rod azimuth angle, into planer and out of plane components, defines the phase angle relationship between the principal curvatures and the sun rod plane.

The mean quantities discussed above can be most readily summarized on a polar plot similar to those used to portray rod bending data shown in Section 2.6 of the Seventh Quarterly Progress Report, Document No. 66SD4318.

2.4.3 ANALYTICAL APPROACH

Assumptions used for rod bending to date are the results of an essentially intuitive approach to the problem. In essence, the overlapped tube is considered as having a mean curvature equal to that of a similar closed tube. A perturbation is superimposed on the mean curvature dependent upon overlap angle and sun rod azimuth angle.

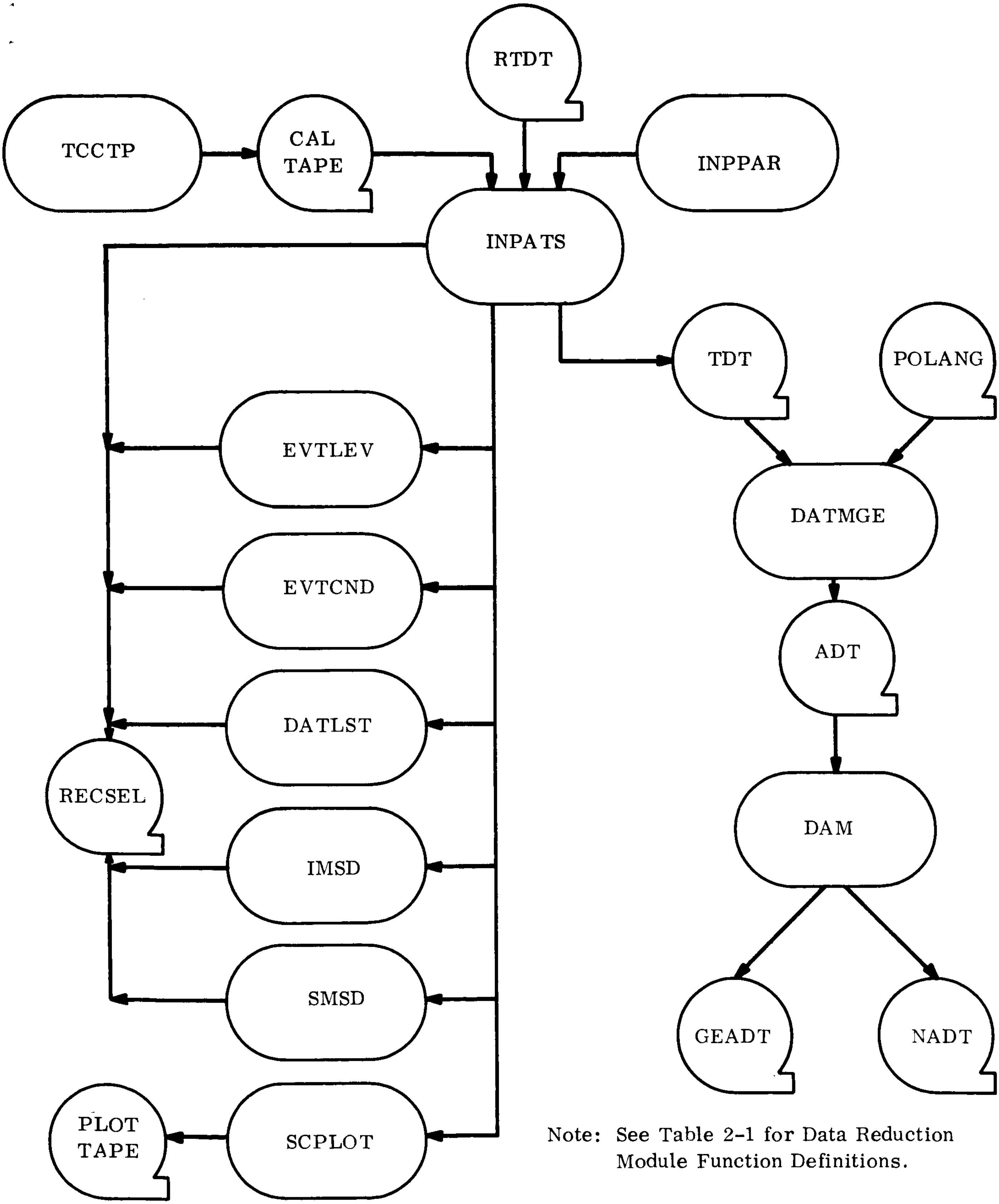
An exact solution to the shell equation, for certain important strain states, for the overlapped rod has been completed by the Franklin Institute. These equations have been programmed for the digital computer for numerical evaluation. The program is currently being debugged. Prior to receipt of the Franklin Institute report, a lumped parameter representation of this problem was developed and solved for approximate stiffness coefficients using matrix methods. The results of the lump parameter analysis are being held for checking results obtained using the exact analysis.

From the above mentioned series of tests, we have gained assurance that the analytic temperature prediction is good. The analytic temperature distribution will be disassociated into components consistent with the strain components accounted for in the exact shell equations, and the system solved for rod displacement. The rod displacement thus determined will be resolved into coefficients consistent with the requirements of the math model rod representation.

2.5 ATS ATTITUDE DETERMINATION

The computer processing system to be utilized for evaluation of the ATS-A spacecraft and the determination of attitude has been completely specified and all modules, submodules, and subroutines are being coded and checked out. Completion date for the system is scheduled for the week of 28 November, at which time the complete system checkout will begin.

The modular system of the computer programs is illustrated in Figure 2-6. By definition, the major functions of the programs are labelled modules; modules composed of submodules and subroutines are defined as elements of submodules. For brevity, the submodules and subroutines within the modules are not described here. The total system description is presented in PIR 4A26-096, "ATS Data Reduction Computer Software System Description," 10 October 1966.



Note: See Table 2-1 for Data Reduction Module Function Definitions.

Figure 2-6. Modular System for Data Processing

Table 2-1. DRM Subroutine Functions

Title	Function
DAM	Computes spacecraft attitude utilizing all sensor and POLANG data available. Logically processes the redundant solutions for the NASA Attitude Data Tape (NADT) for singular solutions at five minute intervals; the GE Altitude Data Tape (GEADT) has all redundant solutions computed at one minute intervals.
DATMGE	Merges telemetry attitude sensor data and POLANG data in a continuous sequence for the computation of spacecraft attitude. It also performs data smoothing and editing as required.
DATLST	Formats continuous listings of selected telemetry words for printout.
EVTCND	Flags event changes for all on/off bit indicators within telemetry words.
EVTLEV	Flags event level changes prescribed by parameter input for all nine-bit telemetry monitors.
IMSD	Computes the mean and standard deviation of selected telemetry words over prescribed time intervals.
INPATS	Unpack and output ATS data from RTDT for subsequent processing; generates the intermediate telemetry data tape (TDT) if required; functionalizes, i.e., converts the data to engineering units; performs checks on sync errors, data fill, data mode, and time code errors.
INPPAR	Formats all parameter inputs to the system and stores them for subsequent processing.
RECSEL	Assigns record selection characters to data outputted from all modules and writes the data on the RECSEL tape for diagnostic listings.
SCPLOT	Formats and scales telemetry data for plotting on the Stromberg-Carlson SC-4020.
SMSD	Computes the mean and standard deviation of selected telemetry words over total files of input telemetry data.
TCCTP	Generates the calibration tape from hollerith card input for data functionalization. The data on cards is taken from the ATS Calibration Book for the particular spacecraft.

2.6 FINAL DESIGN COMPLETION PERFORMANCE ESTIMATES

Final estimates of performance (prior to incorporation of final data on accomplished hardware parameters, system alignment data and magnetic dipole measurements) are presented in Tables 2-2 through 2-5. Assumptions pertaining to these estimates are as follows:

- Orbit Eccentricity = 0.005 (ATS-A)
  = 0.000 (ATS-D)
- Magnetic Dipole = 1000 pole-cm, Y-axis (ATS-A)
  = 1000 pole-cm, Z-axis (ATS-D)
- Internal Disturbances = 0.2 deg all axes
- Stationkeeping (ATS-D only)
  - Thrust Level = 10^{-5} pounds
  - 30 days on/60 days off (SS errors)
  - 1 - degree thrust vector misalignment
- Damper Spring Null Shift = 1 degree
- Surface Properties
  - Boom Reflectivity = 0.85 (specular)
  - Cylindrical Surface = 0.30 (specular)
  - Solar Pressure Ring = 0.30 (specular)
  - Boom Tip Targets = 0.50 (diffuse) 9 - inch diameter
- Solar Pressure = 9.65×10^{-8} lb/ft^2
- Boom Geometry Assumptions (worst case, each axis)
  - Alignment Error = 1.0 degree
  - Initial Straightness = 0.5 ft env. rad. @ 100 ft
  - Boom Shortness = 1.80 ft (ATS-A) - one of each pair
    = 1.64 ft (ATS-D) - one of each pair
- Surface Property Unbalance (worst case, each axis)
  - Central Body Absorptivity Unbalance = 0.10
  - Boom System Absorptivity Unbalance = 0.10
- GAPS IV Model of Thermal Bending

Table 2-2. ATS-A Design Configuration

APPLICATIONS TECHNOLOGY SATELLITE

ATS-A DESIGN CONFIGURATION	SUN 26° TO ORBIT PLANE						Sun in Orbit Plane					
	Pitch		Roll		Yaw		Pitch		Roll		Yaw	
	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc
MAGNETIC ERRORS	0	0.2	0	0	0	1.1	0	0.2	0	0	0	1.1
SOLAR TORQUE AND THERMAL BENDING	0	0.4	0	0.5	0	0.9	0	0.3	0	0.3	0	0.2
ECCENTRICITY = 0.005	0	0.8	0	0.1	0.1	1.0	0	0.8	0	0.1	0.1	1.0
TIP TARGETS	0	< 0.1	0	< 0.1	0	< 0.2	0	0.1	0	0.1	0	0.2
INTERNAL DISTURBANCES (LIMIT)	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2
RSS ERRORS (SEE TABLE 2-3)	0.8	0.2	0.7	0.2	1.4	0.2	0.8	0.3	0.7	0	1.4	0.4
TOTAL SUM OF ERRORS	0.8	1.9	0.7	1.1	1.5	3.6	0.8	1.9	0.7	0.7	1.5	3.1

MOMENTS OF INERTIA

Pitch	Roll	Yaw	Damper	ϕ	α	δ	ξ
1378.4	5804.3	1378.4	231	58.2°	53.4°	-4.8°	25.02°

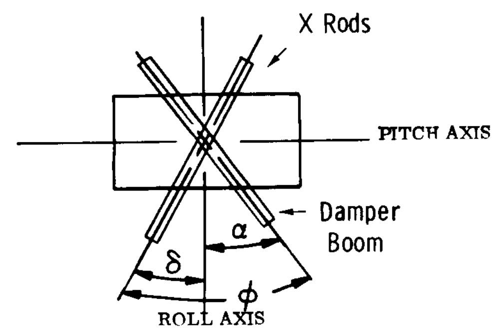


Table 2-3. ATS-A Tolerance Effects

APPLICATIONS TECHNOLOGY SATELLITE

ATS-A	SUN 26° TO ORBIT PLANE						Sun in Orbit Plane					
	Pitch		Roll		Yaw		Pitch		Roll		Yaw	
TOLERANCE EFFECTS	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc
CYLINDER REFLECTIVITY												
END EFFECT	0	0	0	0	0	0	0	0	0	0	0	0
SURFACE EFFECT	0	0	0	0	0	0	0	0	0	0	0	0.1
UNEQUAL ROD ABSORPTIVITY	0	0.2	0	0.2	0.2	0.2	0	0.3	0	0	0	0.3
SPRING NULL SHIFT	0.2	0	0.2	0	0.1	0	0.2	0	0.2	0	0.1	0
ROD SHORTNESS												
PRINCIPAL AXIS SHIFT	0.5	0	0	0	0.1	0	0.5	0	0	0	0.1	0
CENTER OF MASS SHIFT (SOLAR TORQUE)	0	0.1	0	0	0	0.1	0	0	0	0	0	0
ROD NON-STRAIGHTNESS												
PRINCIPAL AXIS SHIFT	0.3	0	0.3	0	0.6	0	0.3	0	0.3	0	0.6	0
0.025 FOOT CENTER OF MASS SHIFT (SOLAR TORQUE)	0	0.1	0	0	0	0.1	0	0	0	0	0	0.2
ROD MISALIGNMENT ANGLE = 1.0 DEGREE												
PRINCIPAL AXIS SHIFT (RMS)	0.5	0	0.6	0	1.2	0	0.5	0	0.6	0	1.2	0
CENTER OF MASS SHIFT (SOLAR TORQUE)	0	0	0	0	0	0	0	0	0	0	0	0
RSS ERRORS (WORST CASE)	0.8	0.2	0.7	0.2	1.4	0.2	0.8	0.3	0.7	0	1.4	0.4

MOMENTS OF INERTIA

Pitch	Roll	Yaw	Damper	ϕ	α	δ	ξ
1378.4	5804.3	1378.4	231	58.2°	53.4°	-4.8°	25.02°

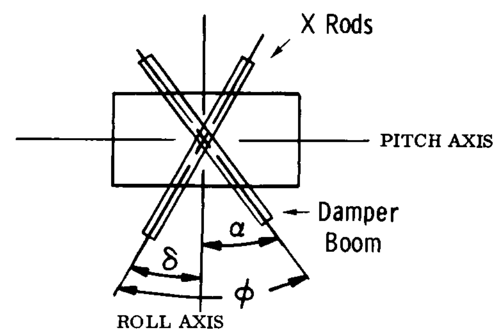


Table 2-4. ATS-D Design Configuration

APPLICATIONS TECHNOLOGY SATELLITE

ATS-D DESIGN CONFIGURATION (ZERO ECCENTRICITY)	SUN 23.5° TO ORBIT PLANE						Sun in Orbit Plane					
	Pitch		Roll		Yaw		Pitch		Roll		Yaw	
	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc
WITH STATION-KEEPING:												
MAGNETIC ERRORS (FIXED FIELD)	0	0	0	0	0.3	0	0	0	0	0	0.3	0
SOLAR TORQUE AND THERMAL BENDING	0.2	1.4	0.1	1.7	0.2	2.0	0	1.3	0	1.2	0	1.1
TIP TARGETS	0	0.2	0	0.2	0	1.1	0	0.1	0	0.1	0	0.7
INTERNAL DISTURBANCES (LIMIT)	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2
THRUSTER ERRORS (30 DAYS ON)	0.1	0.6	0.2	0.1	1.0	2.3	0.1	0.4	0.1	0.4	1.6	2.2
RSS ERRORS (SEE TABLE 2-5)	1.0	1.7	0.7	0.2	7.0	4.2	1.0	1.7	0.7	0.3	2.1	5.9
TOTAL SUM OF ERRORS	1.3	4.1	1.0	2.4	8.5	9.8	1.1	3.7	0.8	2.2	4.0	10.1
WITHOUT STATION-KEEPING:												
MAGNETIC ERRORS (FIXED FIELD)	0	0	0	0	0.3	0	0	0	0	0	0.3	0
SOLAR TORQUE AND THERMAL BENDING	0.2	1.4	0.1	1.7	0.2	2.0	0	1.3	0	1.2	0	1.1
TIP TARGETS	0	0.2	0	0.2	0	1.1	0	0.1	0	0.1	0	0.7
INTERNAL DISTURBANCES (LIMIT)	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2
RSS ERRORS (SEE TABLE 2-5)	0.8	1.5	0.5	0.2	1.5	3.3	0.8	1.7	0.7	0.1	1.4	5.3
TOTAL SUM OF ERRORS	1.0	3.3	0.6	2.3	2.0	6.6	0.8	3.3	0.7	1.6	1.7	7.3

MOMENTS OF INERTIA PITCH	ROLL	YAW	DAMPER	ϕ	α	δ	ξ
16,662	13,591	3158	540.0	58.2	53.4	-4.8	24.94

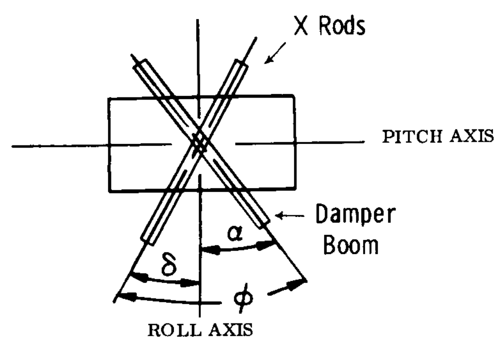


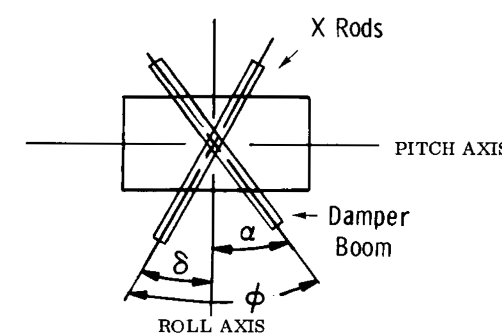
Table 2-5. ATS-D Tolerance Effects

APPLICATIONS TECHNOLOGY SATELLITE

ATS-D TOLERANCE EFFECTS	SUN 23.5° TO ORBIT PLANE						Sun in Orbit Plane					
	Pitch		Roll		Yaw		Pitch		Roll		Yaw	
	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc	Bias	Osc
CYLINDER REFLECTIVITY												
END EFFECT	0	0	0	0	0	0.1	0	0	0	0	0	0.1
SURFACE EFFECT	0	0	0	0	0	0.1	0	0	0	0	0	0.2
UNEQUAL ROD ABSORPTIVITY	0.1	1.4	0	0.2	0.5	1.5	0	1.5	0	0	0	1.6
SPRING NULL SHIFT	0.2	0	0.2	0	0.1	0	0.2	0	0.2	0	0.1	0
ROD SHORTNESS												
PRINCIPAL AXIS SHIFT	0.5	0	0	0	0.1	0	0.5	0	0	0	0.1	0
CM SHIFT 0.1 FT - THRUSTER -30 DAYS	0.4	0	0	0	3.7	0	0.4	0	0	0	3.7	0
CM SHIFT 0.1 FT - SOLAR TORQUE	0	0.3	0	0	0	2.0	0	0.5	0	0.1	0	3.5
ROD ENVELOPE												
PRINCIPAL AXIS	0.3	0	0.3	0	0.6	0	0.3	0	0.3	0	0.6	0
CM SHIFT 0.1 FT - THRUSTER -30 DAYS	0.4	0	0	0	3.7	0	0.4	0	0	0	3.7	0
CM SHIFT 0.1 FT - SOLAR TORQUE	0	0.3	0	0	0	2.0	0	0.5	0	0.1	0	3.5
ROD MISALIGNMENT -1°												
PRINCIPAL AXIS SHIFT	0.5	0	0.6	0	1.2	0	0.5	0	0.6	0	1.2	0
CM SHIFT - THRUSTER -30 DAYS	0.2	0	0	0	4.1	0	0.2	0	0	0	4.1	0
CM SHIFT - SOLAR TORQUE ΔCM 0.025 FT	0	0.1	0	0	0	0.6	0	0.1	0	0	0	0.9
THRUSTER -1° MISALIGNMENT -30 DAYS	0.1	0.7	0.1	0	1.7	4.1	0	0.4	0.1	0.3	0.3	2.3
RSS ERRORS NO THRUSTER	0.8	1.5	0.5	0.2	1.5	3.3	0.8	1.7	0.7	0.1	1.4	5.3
RSS ERRORS WITH THRUSTER	1.0	1.7	0.7	0.2	7.0	4.2	1.0	1.7	0.7	0.3	2.1	5.9

MOMENTS OF INERTIA

Pitch	Roll	Yaw	Damper	ϕ	α	δ	ξ
16,662	13,591	3158	540.0	58.2	53.4	-4.8	24.94



SECTION 3

BOOM SUBSYSTEMS

3.1 KEY EVENTS

11 August 1966	Prototype No. 1 and Flight No. 1 Damper Booms returned to deHavilland for rework.
18 August 1966	Prototype No. 1 Primary Boom received from deHavilland.
1 September 1966	Start of qualification test cycle on Prototype No. 1 Primary Boom.
3 September 1966	Flight No. 1 Damper Boom received from deHavilland with new elements installed.
3 September 1966	Flight No. 1A Primary Boom received from deHavilland.
9 September 1966	Flight No. 1B Primary Boom received from deHavilland.
10 September 1966	Start of acceptance test cycle on Flight No. 1A Primary Boom.
15 September 1966	Start of acceptance test cycle on Flight No. 1B Primary Boom.
15 September 1966	Start of acceptance test cycle on Flight No. 1 Damper Boom.
19 September 1966	Prototype No. 1 Damper Boom received from deHavilland after rework to ATS-D/E configuration.
28 September 1966	Start of acceptance test cycle on Prototype No. 1 ATS-D/E Damper Boom.
10 October 1966	Flight Unit No. 1B Primary Boom returned to deHavilland for rework.
17 October 1966	Flight Unit No. 1A Primary Boom returned to deHavilland for rework.
26 October 1966	Flight No. 1 Damper Boom shipped to HAC.
28 October 1966	Flight Unit No. 1B Primary Boom received from deHavilland after rework for sheared pins.

31 October 1966	Flight Unit No. 1A Primary Boom received from deHavilland after rework of sealed drive shaft misalignment.

3.2 UNIT IDENTIFICATION

The designations and use of the Primary and Damper Boom Systems are listed in Table 3-1.

3.3 PRIMARY BOOMS

3.3.1 ENGINEERING UNITS

All activity involving the use of the engineering units has been completed and no further use is planned. The units are in the possession of GE awaiting disposition by NASA/GSFC.

3.3.2 PROTOTYPE UNIT P-1 (S/N 100)

3.3.2.1 Initial Testing

Primary Boom S/N 100 failed to extend on 6 August while set up in the alignment fixture at deHavilland. The motor, diodes and other components were checked individually and were found to be normal. When the unit was re-assembled, it operated normally and the booms were extended. A deHavilland disposition report (No. 119752) stated: "Unit acceptable as is. Full investigation and analysis of apparent malfunction to follow." Their final report attributed the malfunction to the possibility that the unit was scissored to the full negative limit of negative travel (i.e., 11 degrees) before boom extension was attempted. However, the exact scissor position during the original deHavilland tests did not appear to be known exactly. But in later results of tests in the thermal-vacuum chamber at GE, an interference was uncovered in the extension drive, when the booms were scissored to the full negative limit, that involves the polycarbonate housing in the erection unit suspension system. At the minimum scissor angle, the polycarbonate housing did not have proper clearance with one of the gears in the extension drive train, and the housing was found to engage the drive train, thus stalling the motor. The scissoring problem was solved during qualification testing at GE. See Section 3.3.2.2.1.

Table 3-1. Boom System Identification

Designation		Serial No.	Use
<u>Engineering Units</u>			
T-1a	Primary Boom	EU 1	
T-1b	Primary Boom	EU 1	
T-1	Damper Boom	EU 1	
<u>Prototype Units</u>			
P-1	Primary Boom	S/N 100	Component Qualification
P-2a	Primary Boom	S/N 11	System Qualification
P-2b	Primary Boom	S/N 12	System Qualification
P-1	Damper Boom	S/N 11	Component Qualification
P-2	Damper Boom	S/N 12	System Qualification
<u>Flight Units</u>			
F-1a	Primary Boom	S/N 10	Flight Unit, ATS-A
F-1b	Primary Boom	S/N 101	Flight Unit, ATS-A
F-2	Primary Boom	S/N 102	Flight Unit, ATS-D/E
F-2	Primary Boom	S/N 103	Flight Unit, ATS-D/E
F-3	Primary Boom	S/N 104	Flight Unit, ATS-D/E
F-3	Primary Boom	S/N 105	Flight Unit, ATS-D/E
F-1	Damper Boom	S/N 100	Flight Unit, ATS-A
F-2	Damper Boom	S/N 101	Flight Unit, ATS-D/E
F-3	Damper Boom	S/N 102	Flight Unit, ATS-D/E

During initial functional test of the P-1 unit at GE, two pins in the scissor drive train were sheared when the erection unit was inadvertently run into two anchored nuts that retained a cover strip, and the scissor limit switches were prevented from stopping the scissor motor. Clearance in the area of the anchor nuts is critical, so the anchor nuts were removed from the design to prevent recurrence. The shear pins were replaced without the need to remove the bell crank housing cover. After the pre-welding vibration shakedown test, the P-1 unit failed to uncage. Investigation revealed that the latching cables in the unit were not the latest design and caused the tip plugs to jam. The cables were changed.

The P-1 unit was reworked at GE in an effort to locate leaks that occurred in the pressurized hermetically sealed transmission box. As a result of one of these reworks, the unit was successfully pressurized and sealed, and the leak rate was found to be 10^{-7} cc/sec or less, which is an order of magnitude better than the specification requirement. The P-1 unit was then committed to the qualification cycle.

3.3.2.2 Qualification Testing

Component qualification testing of the P-1 Primary Booms was begun on 1 September. These tests included several pre-environmental checks and full operation. The qualification series was conducted in the following sequence:

a. Visual Mechanical Inspection
b. Circuit Isolation and DC Resistance
c. Insulation Resistance
d. Dielectric Strength
e. Leak Test
f. Extension and Retraction
g. Scissoring
h. Electrical Isolation
i. Humidity
j. Circuit Isolation and DC Resistance
k. Vibration
l. Circuit Isolation and DC Resistance
m. Magnet Dipole
n. Thermal-Vacuum
o. Circuit Isolation and DC Resistance
p. Acceleration

q. Leak Test

r. Circuit Isolation and DC Resistance

s. Insulation Resistance

t. Dielectric Strength

u. Straightness and Alignment

v. Extension and Retraction

w. Scissoring

x. Electrical Isolation

From 12 to 23 September, the P-1 prototype was subjected to the qualification-level environments of vibration and humidity. Results were within specification, and these tests confirmed the changes made to the design that previously resulted in tip weight uncaging, element cracking, bearing hang-up in the kidney slot, and element cracking at the attachment to the end caps. The unit was then exposed to the thermal-vacuum cycle, the profile of which is shown in Figure 3-1. Boom deployment was restricted to short distances, in accordance with the test plan, and scissoring was performed with the tip plugs removed.

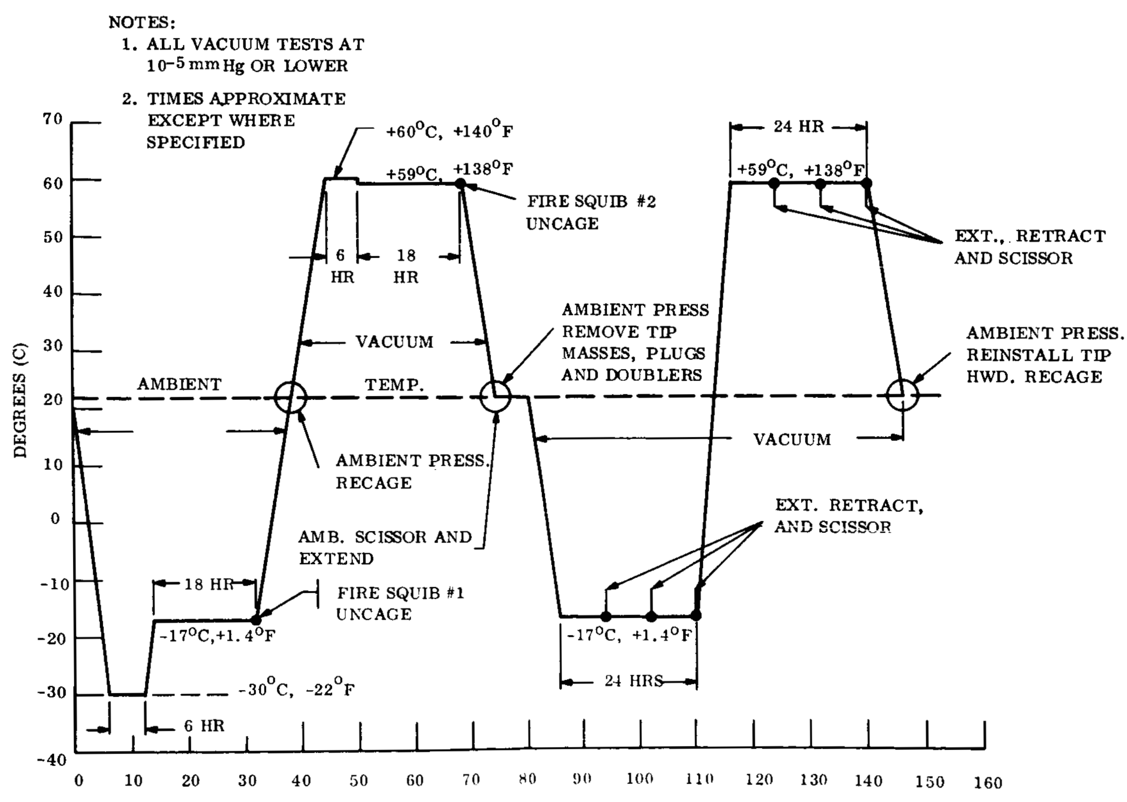


Figure 3-1. ATS Primary Boom, Qual T/V Cycle

The extension motor stalled during thermal-vacuum testing but only at the minimum scissor angle of 11 degrees; all other qualification tests were conducted successfully.

3.3.2.2.1 Motor Stall

When the unit was in the thermal-vacuum environment and functioned in the operational phase (i.e., without tip masses), attempts to extend or retract the booms resulted in a stall condition of the extension motor as evidenced by high armature current (between 2.5 and 3.5 amperes). Motor stalling occurred at both extremes of temperature and vacuum, and also at ambient temperature and pressure only at the extreme negative of scissor angle; they were operated normally at any other scissor angles, including the positive scissor limit (i.e., 30^{o}). The high armature current was a measure of the fact that a high mechanical resistance existed to motor torque. An investigation of the gear mechanism revealed that the polycarbonate housing was the cause of the resistance.

The polycarbonate housing is basically a plastic ring that is part of the erection unit suspension system on which the erection unit moves about the scissor axis. There is a slot on the circumference of the ring to allow clearance of the gear in the scissor drive train. When the scissor motion was moved to one of the extremes, slot clearance was exceeded, and the gear was stopped against the edge of the slot, thus effectively stalling the extension motor. The corrective action taken to prevent this motor stall condition was to sufficiently widen the slot in the polycarbonate ring so that the gear would not contact the ring even at minimum scissor angle.

The S/N 100 Primary Boom was considered to have passed the qualification tests through the thermal-vacuum environment since the malfunction of motor stalling was not a function of the environments but was the cause of a dimensional incompatibility.

3.3.2.2.2 Tip Plug Uncaging Tests

Based on results of the flight unit after exposure to the thermal tests in the acceptance series, (to be discussed later) NASA directed that an investigation be made to determine the adequacy of the tip plug uncaging springs to unlatch the plugs. Thus, the qualification of the S/N 100 unit was interrupted and it was used as a test bed to evaluate spring performance. The uncaging force of the existing design supplies a maximum uncaging force of 3.7 pounds at the fully compressed position. Increasing this force to a significantly higher value was not borne out by the results of early testing because an uncaging force of 5 pounds or greater on each boom would bind the transmission unit. Calculations of side loads indicated that an uncaging force of 3.7 pounds was the minimum required to uncage against the effect of side loads. However, a recalculation of the side load requirements turned up an error in the size of the scissor bellows used to apply the side loads, and the actual force could be reduced by one-half.

Based on the experience gained as a result of this series of tests, it was decided that a spring gradient somewhat less than the current spring, would maintain uncaging forces at a higher level all the way to the end of the uncaging stroke. A new uncaging spring was designed which delivered the 3.7 pound preload force of the former spring but which now delivered a greater fraction of this force at the end of the uncaging stroke. The redesign not only included a change in the spring but also a change in the space which is associated with the tip plug. The design was accomplished for all units including prototype and flight equipment.

After evaluation of the uncaging spring, the qualification program, involving the Prototype S/N 100 Primary Boom, was resumed at the point of completion of the thermal-vacuum tests. The remaining tests in the qualification cycle included: leak test and evaluation, dipole measurement, and full extension and retraction of the booms on the 150-foot test track at GE. At the completion of the planned qualification program, two anomalies were evident: (1) the sealed drive chamber that is maintained at 7.5 pounds pressure was found to be leaking, and (2) boom deployment on the test track stalled at between 20 to 30 feet of extension. A plan was undertaken to troubleshoot the cause of both problems.

3.3.2.2.3 Sealed Drive Leak

A review of the qual test date revealed that the leak was first evident in the thermal-vacuum cycle, although the leak was not apparent until the unit had soaked at ambient conditions of pressure and temperature for several days. The unit was artificially pressurized using helium, and a sniff test revealed the location of the leak to be near the hermetic sealed connector which penetrates the pressure wall in the area of the wire duct. The connector is brazed to the wall of the pressure shell and is guaranteed by the manufacturer to be leakproof. The unit was returned to deHavilland with instructions to repair the leak.

3.3.2.2.4 Boom Retraction Anomaly

The program that was undertaken to isolate the cause of the boom drag showed that deployment not only stopped between 20 and 30 feet of tape, but the condition deteriorated to the point of a bearing seizure. The bearing involved is located on the upper bearing of the wobble bellows assembly (which is the uppermost bearing of the three bearings mounted on a single shaft). An excessive amount of debris was discovered in the affected bearing, but the source of this debris was not identified. The problem is currently under analysis by GE, deHavilland, and the bearing manufacturer.

3.3.3 PROTOTYPE UNITS P-2a (S/N 11), P-2b (S/N 12)

The P-2a and P-2b Primary Boom units are designated as the System Qualification units. These units were shipped to HAC for evaluation with the ATS spacecraft. They have been subjected to functional tests while mounted in the spacecraft, vibration tests, and system thermal-vacuum tests. A status of these units is given in Section 6.

3.3.4 FLIGHT UNITS

3.3.4.1 F-1a (S/N 10) and F-1b (S/N 101) Unit Summary

Both Flight Unit F-1a and F-1b were delivered to GE with the top covers of the transmission unit not welded, and a pre-planned shake test and a functional test were conducted before the covers were welded in position. Both units were then tested to the ATP procedure in accordance with the applicable GE Standing Instruction. The acceptance series included the following:

a. Visual Mechanical Inspection
b. Circuit Isolation and DC Resistance
c. Insulation Resistance
d. Dielectric Strength
e. Leak Test
f. Extension and Retraction
g. Scissoring
h. Electrical Isolation
i. Vibration
j. Circuit Isolation and DC Resistance
k. Thermal-Vacuum
l. Magnet Dipole
m. Dielectric Strength
n. Insulation Resistance
o. Circuit Isolation and DC Resistance
p. Leak Test
q. Electrical Isolation
r. Scissoring
s. Extension and Retraction
t. Straightness and Alignment

During the thermal-vacuum test (see Figure 3-2 for the temperature profile) both units encountered an uncaging difficulty at low temperature and with the tip mass deployment trolleys installed; the trolleys are part of the test equipment. Failure was attributed to the action of the test trolleys and repetition of the tests, without the trolleys, resulted in proper operation in every test. However, the details of the malfunctions are reported in GE Failure Analysis Report 255-E-26 (S/N 10 unit) and 249-E-25 (S/N 101 unit). The highlights of both failure reports are presented here for reference.

Failure Analysis 255-E-26

The F-1b Primary Boom (S/N 10) failed to uncage during thermal-vacuum test at cold temperature (-7°C) on 20 September 1966. This followed a similar failure of the F-1a Primary Boom (Reference Failure Analysis Report 249-E-25). Flight pyro release mechanism and live squibs had been installed and the vibration test performed. For thermal-vacuum, the test trolleys were aligned to the unit and attached to the tip masses. After Squib 1 was fired, a 200 millisecond pulse at 26 volts produced only a slight movement of the tip plugs. Three additional pulses from the uncaging panel and several using the deploy panel produced no further movement of the tip plugs or tip masses.

The vacuum chamber was vented back and the unit examined. It was found that Squib 1 had fired, the holding pin sheared, and the release mechanism operated properly. Both test trolleys were on the track and their wheels were free. The tip plug had extended approximately 5/8 inch.

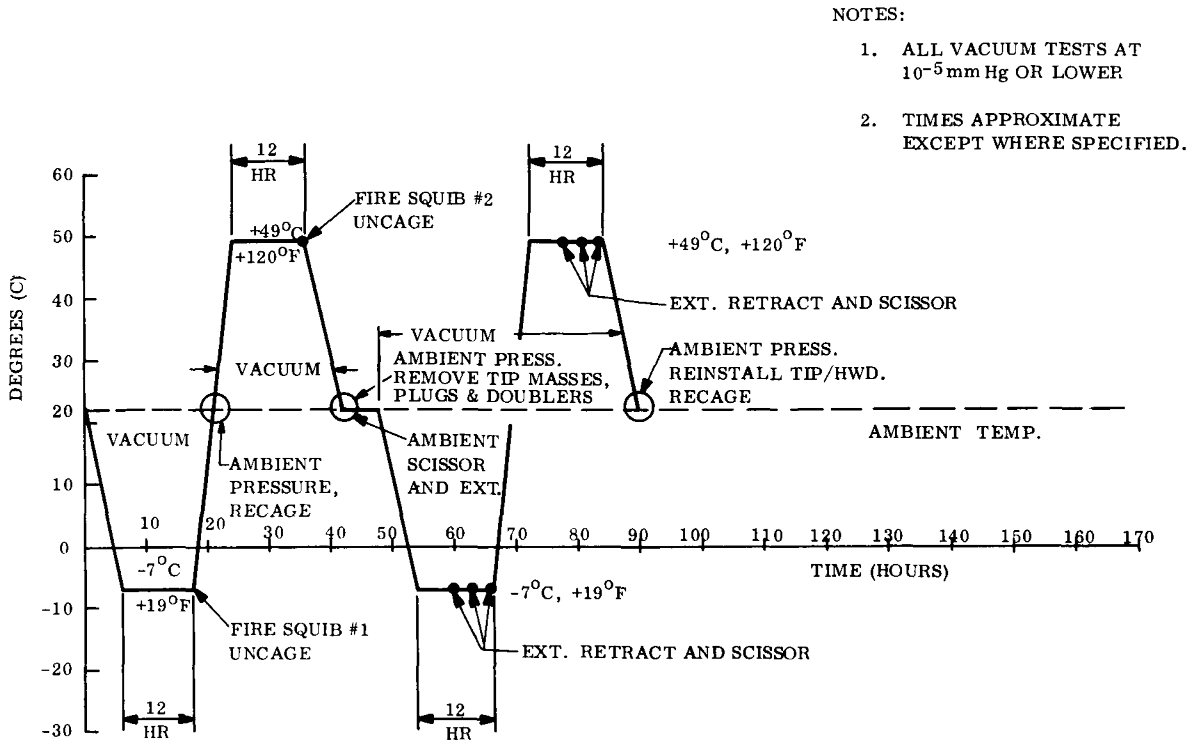


Figure 3-2. ATS Primary Boom, Acceptance T/V Cycle

With the trolleys still attached, the chamber was pumped down to partial vacuum (100 microns). With the unit at room temperature, the tip masses uncaged satisfactorily at 26 volts with one pulse. The chamber was returned to atmospheric pressure, the tip masses removed, and the boom elements deployed and retracted several times. Tip masses were reinstalled and the trolleys attached. The trolleys were found to be out of alignment and set-up was repeated. The unit uncaged satisfactorily at 26 volts with two pulses.

There was no malfunction of the pyro release mechanism and it operated properly. Although the S/N 101 unit uncaged at room temperature with the test trolleys attached, analysis of the S/N 10 and S/N 101 failures indicates that both are associated with the use of test trolleys at cold temperature. That this is the actual cause is confirmed by the successful uncaging of both units at cold temperature with the trolleys removed. Incomplete uncaging with partial movement of the tip plug, and the observed backwinding, were probably caused by trolley misalignment and binding.

Although the failures of both units immediately followed vibration tests and successful uncagings did not, there is no evidence that the failures were related to vibration. This is supported by the successful uncaging of the S/N 100 (Qual) unit, at both hot and cold temperature following vibration and acceleration tests. In this case also, the test trolleys were removed.

Failure Analysis 249-E-25

The F-1a Primary Boom (S/N 101) encountered uncaging difficulty during the thermal-vacuum test at cold temperature. A similar failure occurred with the F-1b (S/N 101) Primary Boom (Reference Failure Analysis Report 255-E-26). The pyro mechanism was installed, including flight type shear pin, live squibs, and flight thrusters. Vibration test and post-vibration electrical check were satisfactory. The thermal-vacuum uncaging test was performed at $-7^{o}C$ on 19 September 1966, with tip masses attached to the test equipment trolleys. After Squib 1 was fired, the unit failed to uncage at 26 volts with four, 200 millisecond pulses from the uncaging panel and three longer pulses using the deploy panel. After Squib 2 was fired, the unit uncaged satisfactorily on the second 200 millisecond pulse. The unit was removed from the chamber and successfully caged at 26 volts, and uncaged at 22 volts with latching cables both removed and installed. It was again tested in thermal-vacuum at $-7^{o}C$ temperature on 23 September 1966. The test equipment trolleys were removed for this test. The unit uncaged successfully at 26 volts with a single pulse.

The conclusion is that Squib 1 sheared the pin and that the uncaging difficulty was due to misalignment of the test equipment trolleys.

During the extension of S/N 10 for installation of new tape elements, a very sudden stall condition of the extension motor developed. Subsequent operation of the motor resulted in extremely slow motor operation; the motor was drawing very nearly stall current. Failure Analysis Report 256-E-27 is an accurate narrative of the history and analysis of the malfunction and is included here as follows:

Failure Analysis 256-E-27

During extension and retraction test on 14 October 1966, the extension motor operation became sluggish and stalled. Retraction of the boom element stopped. The unit was mounted on the test track. Installation of new elements had previously been completed, and snubbingwas checked and found satisfactory. For the first deployment, Boom 2 was attached to the test trolley and deployed, and Boom 1 was attached to the takeup mechanism. The limit switch actuated before the element was fully deployed, and was released manually. On retraction, the limit switch did not shut off until approximately the 80 foot mark. The switch was readjusted and operated satisfactorily through the remainder of the test. Boom 2 extended 123 feet, 8-3/4 inches in 2 minutes and 13.4 seconds. Extension rate was 0.928 ft/sec. Specification requirement is 1.2 ± 0.3 ft/sec for extension and retraction. Boom 2 retracted 124 feet, 11-1/4 inches in 2 minutes 58.4 seconds. Retraction rate was 0.703 ft/sec.

On the second deployment, Boom 1 was attached to the test trolley and Boom 2 to the take-up mechanism. Boom 1 extended from 23 feet, 6 inches to 130 feet, 6 inches in 1 minute and 36.4 seconds, a rate of 1.11 ft/sec. Retraction appeared to be satisfactory from full deployment to the 56 ft mark (74 feet 6 inches travel from full extension). At this point, it slowed down and motor armature current increased from 0.85 amp to 2 amps. Movement stopped completely at the 46 foot mark.

Both erection units were disengaged and were found to operate freely with no resistance. They were re-engaged and deployed from the 46 ft mark. The elements moved approximately 20 ft and nearly stopped. Power was shut off and both drive gears were disengaged. The extension motor was actuated in deploy and retract directions at 30 volts. Motor operation was sluggish and armature current was 1.8 amps in both directions. The boom elements were fully retracted manually and the unit inverted. Armature current remained approximately 2 amps in both directions.

The transmission cover was removed, and the gear box was examined by deHavilland representatives. There was no foreign material evident. A bearing seal ring had dropped off the drive gear bearing in the 5398D13-1H transmission plate. A retaining nut on the bellows drive shaft bearing was found to be loose. Clearance was checked between the drive gear and the bellows drive housing and found satisfactory (approximately 0.020 inch).

The extension motor was again operated with drive gears disengaged. At 22 volts, armature current was 2 amps with a partial stall condition. At 30 volts, armature current was 1.5 amps with partial stall. Brake operation was checked by increasing voltage gradually from 0. The brake was heard to release at approximately 10 volts.

Data sheets indicate that the extension motor had 35.5 hours operating time when delivered to deHavilland by their vendor, and 36.5 hours when the unit was delivered to GE. It has been operated approximately 0.5 hours at GE.

The test console was checked and appeared to be satisfactory. A second console was used for the bench tests of the motor and transmission, with no significant change in results.

The unit was returned to deHavilland on 17 October 1966 for additional investigation and failure analysis.

The cause of the failure was attributed to a misalignment of the topmost bearing in the wobble bellows assembly by approximately 3.5 degrees. The misalignment resulted from the mislocation of a spot face (a form of countersink) which caused the flange of the spot face to ride up. The bearing housing was thus misaligned with the shaft. The corrective action taken was to correctly re-locate the spot face.

It is to be noted that although there was a bearing malfunction in both Flight Unit S/N 10 and Prototype S/N 100, investigation later showed that the cause of the problems are not related, and that further investigation of the prototype anomaly will be continued.

The S/N 101 unit was returned to deHavilland for repair; this included removal of the offending shaft by cutting a hole in the bell crank housing, and repair of the hole in the pressure shell. The Acceptance Test Procedure of S/N 101 was completed after it was returned from deHavilland, including installation of one tape. The other element was damaged during installation, and a replacement tape has been shipped from deHavilland.

3.4 DAMPER BOOM

3.4.1 ENGINEERING UNIT

All planned tests involving the T-1 Damper Boom have been completed, and the unit is retained by GE awaiting disposition from NASA/GSFC.

3.4.2 PROTOTYPE UNIT P-1 (S/N11)

Upon receipt of this unit from deHavilland, the prescribed qualification tests were begun by GE. This series included the following tests:

a. Visual Mechanical Inspection
b. Electrical Test
c. Performance Test
d. Alignment and Straightness Check
e. Electrical Tests
f. Thermal-Vacuum
g. Magnetic Dipole
h. Electrical Test
i. Humidity
j. Electrical Test
k. Vibration while mounted to CPD
l. Electrical Test
m. Performance Tests
n. Electrical Test
o. Visual Mechanical Inspection
p. Acceleration while mounted to CPD
q. Alignment and Straightness

During the vibration test, a small crack developed in the tape. This history and analysis of the difficulty was reported in Failure Analysis 228-E-17. This report is included in the following paragraphs.

Failure Analysis 228-E-17

During three vibration tests the Prototype 1 Damper Boom Assembly developed two tears in boom element tapes, and failed to deploy as a result of a rough storage drum bearing.

a. History of Test No. 1

The Damper Boom Assembly was vibrated at GE on the C-125 shaker on 11 June 1966 while mounted on the Prototype 1 CPD. The test was performed to procedure SI 237016, Appendix A, Mated Vibration and Acceleration Tests (Combination Passive Damper). It was later found that the CPD had been incorrectly mounted on the vibration fixture, causing the Damper Boom Assembly to be rotated 90 degrees about its damping axis from the proper position. Also on this test, the recording accelerometers on the boom came loose and fell off at approximately 180 cps during the thrust axis test. The test was stopped at this point, resumed at 10 cps, and repeated.

The Damper Boom was returned to deHavilland on 22 June 1966 for deployment and examination. Deployment was normal and within specification. When the covers were removed it was found that one tape had sustained a tear approximately 5/32-inch long at one edge. This tear was located at the point where the tape is tangent to the storage drum in stored condition. DeHavilland issued Operation Difficulty Report No. 18, dated 14 July 1966. The tear was in the Boom B element tape (No. 2 erection unit) but was designated tape A in this report, apparently in error. The torn tape attached nearest to the damper mounting flange of the center section.

No rework was done at deHavilland. The tape was rewound and the unit was returned to GE on 19 July 1966. Covers were removed and both tapes photographed (See Figures 3-3 and 3-4). Examination showed that tape B was torn and tape A was wrinkled in the storage drum tangential area. The storage drums were untorqued when photographed, hence the wrinkling appears more pronounced than with the tape under tension.

The unit was set up in the test track and an extension test performed 23 July 1966. The boom elements were deployed three times. On the first run, tape A extended in 36 seconds and tape B stopped after one foot. It was suspected that the oscillation dampers attached to the counter balance weights were causing boom element binding. The oscillation dampers (test equipment) were removed to allow the tip masses to float freely around their support points. Approximately one foot was cut from tape B to remove the cracked section. On the final deployment, both booms extended satisfactorily (Boom B: 44 feet 4-1/2 inches in 24.5 seconds, and Boom A: 45 feet 3 inches in 24 seconds).

A fix was incorporated by the deHavilland representative. An 8-inch doubler was added to each boom to stiffen the section of tape from the storage drum to the center section attachment point.

b. History of Test No. 2

The Damper Boom Assembly was again vibrated to qualification levels on 27 July while mounted on the dynamic model CPD. It was oriented correctly with the boom axis in the plane of the Z (launch) axis. On completion of the test, the A tape was found to be cracked near the storage drum tangent point. (The opposite tape cracked on the earlier vibration test.) Both tapes were distorted and billowed on the storage drum. IR 15668 was written,

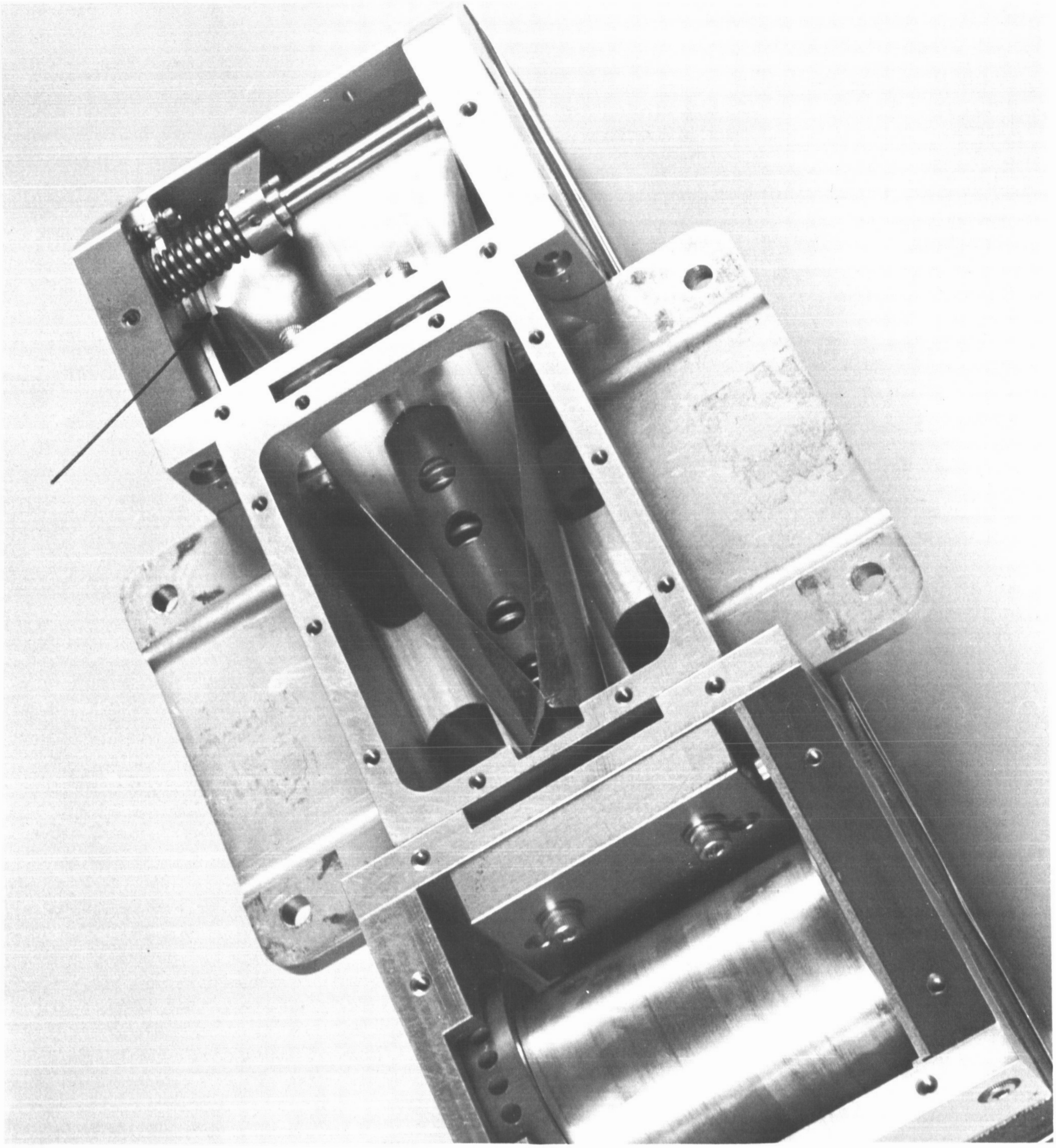


Figure 3-3. Tear in Boom Element B Following First Vibration

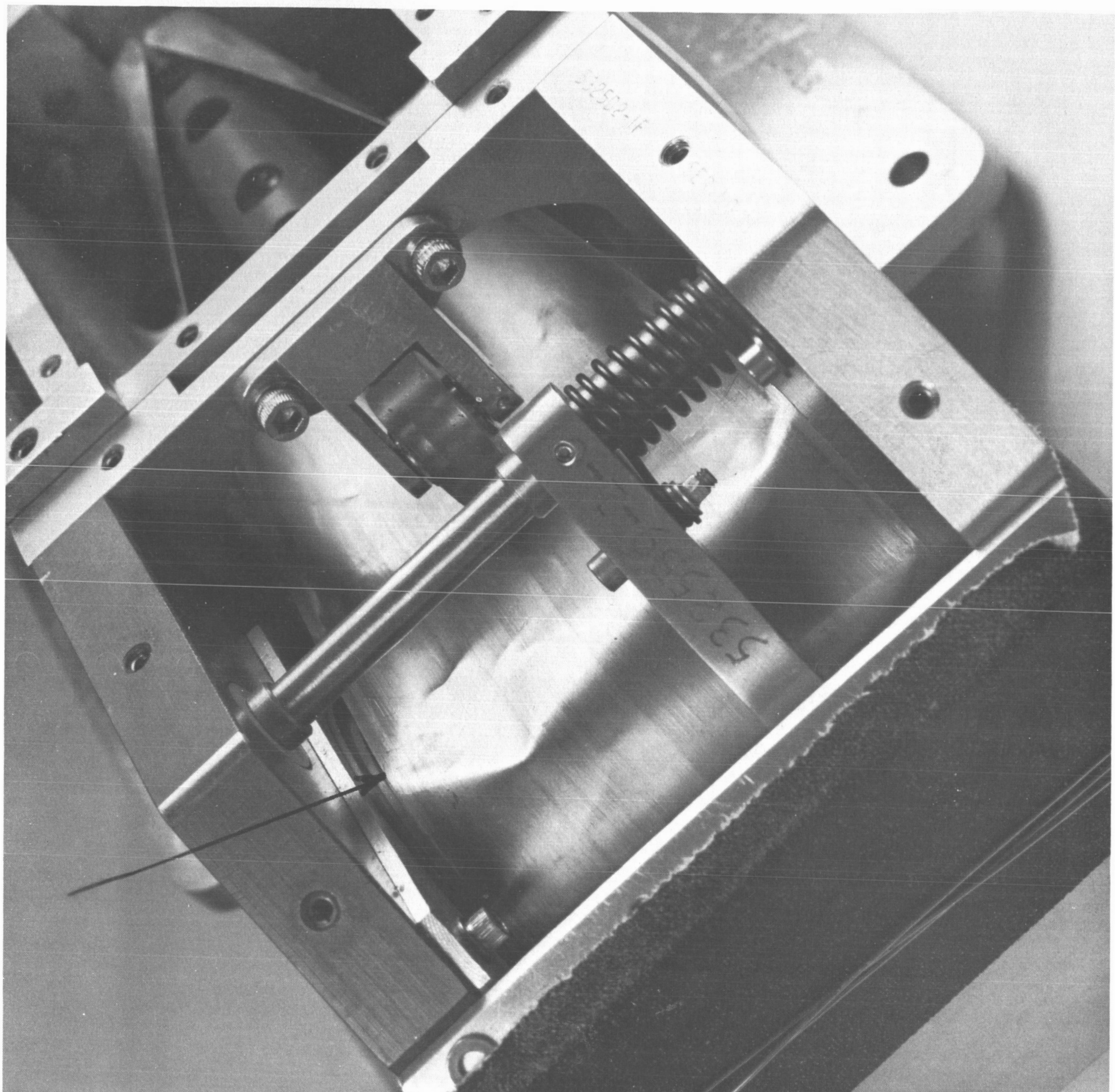


Figure 3-4. Wrinkling in Boom Element A (Untorqued)

and was dispositioned to remove the doubler tapes and to replace the old tapes with new elements. The tapes were replaced at GE by deHavilland representatives. The tapes were rewound and retorqued to a revised procedure intended to prevent billowing under vibration.

c. History of Test No. 3

A third vibration test to qualification levels was performed on 2 August 1966 with the unit mounted on the dynamic model CPD and correctly oriented. The boom elements were torqued to 11 in.-lb for this test. On completion of the test, some billowing was noted on the reels and the tape was elastically buckled. A deployment test was performed 3 August with the unit mounted on the test track. DeHavilland was not represented at this time. The boom elements were released manually and Boom B deployed normally. Boom A extended approximately one foot and stopped. An uneven drag on the storage drum appeared to prevent the boom from deploying properly. The booms were rewound manually. IR 15668-NOA-1 was written.

Tip mass A was removed and disassembled on 6 August by a deHavilland representative. The bearing at the brake end of the storage drum shaft was found to be very rough. Fine black dust was found deposited in the brake area. A metallic sliver approximately 3/16 inch long was found on the opposite (nondamaged) bearing, lying on the outer race near the seal.

The remainder of the assembled unit and the disassembled tip mass were returned to deHavilland on 8 August 1966. DeHavilland was requested to replace all four bearings.

d. Analysis of Test No. 1

The incorrect orientation of the Damper Boom on the first vibration test increased the degradation on the storage drum bearings by a factor of approximately 1.5, contributing to later bearing failure. Vibration data from the CPD test shows that loss of the accelerometers resulted in one additional load cycle from 10 to 180 cps in the thrust axis.

Due to incorrect orientation, the boom element tape was subjected to increased G-loadings. In view of the later tape failure when correctly oriented this does not appear to have been a significant factor in tape failure. Failure to deploy on the early run resulted from misalignment of the tape entry angle into the tip mass caused by malfunction of the test equipment damper. This was aggravated by irregularities in the test track caused by poor adhesion of teflon tape at track joints.

e. Analysis of Test No. 2

Loose rewinding of tape on the storage drum probably resulted in excess loads being imposed on a sensitive area of the tape during vibration. The weak point in the boom element tape occurs at the transition between the storage drum tangent point and the roller area. The tape was rewound by deHavilland in accordance with the power rewind procedure. It was loose after vibration, similar to Test No. 1. Addition of the doubler apparently did not provide positive support and did not compensate for looseness of tape on the drum.

f. Analysis of Test No. 3

The last failure to deploy was associated with a very rough bearing on the storage drum. This probably had existed for some time as a result of vibration and grew progressively worse. The bearing seals were removed and the race, balls, and separator cleaned with solvent (genosolv). No change in roughness was noted, indicating that the race was pitted.

Fatigue analysis of the bearing was performed by using the concept of cumulative damage. The analysis indicates possible bearing failure on second and third vibrations at qualification level. For acceptance tests, a bearing capacity of 15 complete test cycles was predicted.

The black dust found in the brake area was apparently a normal product of wear between the nickel plated copper brake shoe and the anodized aluminum brake bearing surface. The anodized coating was not worn through. The metallic sliver was found to be nickel but its source has not been determined.

g. Conclusions of Test No. 1

Increased vibration levels due to misorientation are not considered the critical factors, since tape failure also occurred on the second vibration test. Failure to extend was caused by the method of support and damping used in the test trolley. The tape crack was caused by looseness on the drum.

h. Conclusions of Test No. 2

Tape tension and storage drum tightness, controlled by rewind torque, will provide adequate restraint at the critical tangent point. Kinking may be accentuated by manually forcing the tip masses into caging position.

Addition of the short doubler on the tape did not provide adequate support to compensate for billowing of the tape.

i. Conclusions of Test No. 3

Failure to deploy was the result of excessive bearing friction caused by brinelling during vibration. Bearing life is not adequate for more than one qualification level vibration. It is adequate to meet acceptance level requirements satisfactorily.

The tape was torqued to 11 in.-lb but this may be marginal. There was no tearing, but billowing was found. Use of higher tape tension should be investigated.

The black powder was deposited principally in the annulus around the braking area. Neither this nor the metal chip appeared to contribute to the bearing failure or the failure to deploy.

In summary, the tears in the damper boom elements were attributed to a lack of a storage drum rewind procedure. The corrective action includes a torquing of the storage drum to 11 in.-lb upon rewind and retention of this torque by proper adjustment of a boom locking screw. Subsequent deployment of the damper boom was accomplished within the rate and coordination required by the specification after exposure to two acceptance level vibration tests. No cracks were evident in the element. Based on this series of tests, it is assumed that torquing of the drum to 11 in.-lb is adequate for flight application.

Exposure of the P-1 prototype unit to the thermal-vacuum tests was conducted in accordance with the cold and hot temperatures shown in Figure 3-5. The test was completed without incident. Boom deployment tests are planned at both high and low temperature. Upon successful completion of these tests, the P-1 will be considered qualified.

3.4.3 FLIGHT UNIT F-1 (S/N 100)

The element in Flight Unit 1 Damper Boom was damaged as a result of test equipment malfunction during an alignment check in the water tank facility at GE. A new tape was installed by deHavilland. The unit was accepted by NASA and shipped to the spacecraft contractor.

3.4.4 FLIGHT UNITS F-2 (S/N 101), F-3 (S/N 102)

These Flight Unit Damper Booms were in the manufacturing cycle at deHavilland at the end of this reporting period. Upon successful completion of the ATP, these systems will be placed in bonded storage at GE for later delivery.

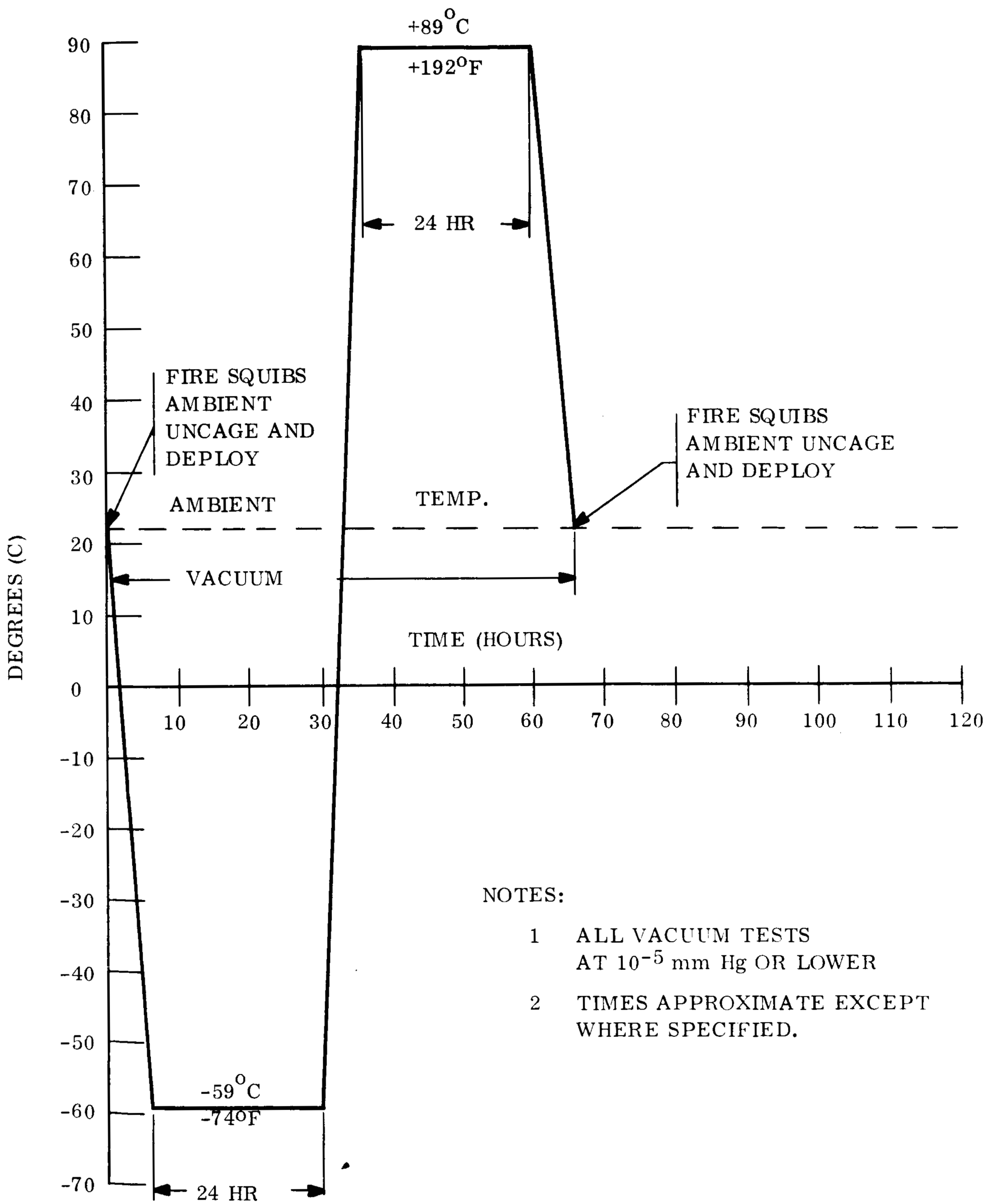


Figure 3-5. ATS Damper Boom, Qual Thermal-Vacuum Cycle

SECTION 4

COMBINATION PASSIVE DAMPER

4.1 STATUS OF HARDWARE

a. Engineering Unit 1 - No further work planned on this unit.

b. Engineering Unit 2 - Unit has been partially disassembled following second qualification vibration test and post-vibration test to evaluate redesigned torsional restraint magnet mounting bracket and bonded retaining ring.

c. Prototype 1 - The unit has been completely disassembled following failure of the torsional restraint magnet mounting bracket (see Section 4.4.3 and Figure 4-1). All parts have been X-rayed and zygloed with no evidence of other problem areas. It is not anticipated that this unit will be reassembled as qualification testing is being completed on Engineering Unit 2.

d. Prototype 2 - This unit was delivered to HAC on 11 May 1966.

e. Flight Unit 1 - Flight Unit 1 CPD was shipped to HAC on 26 October 1966.

f. Flight Unit 2 - Assembly is complete and acceptance testing has started.

g. Flight Unit 3 - Unit is in the final manufacturing stages.

4.2 DRAWINGS AND SPECIFICATIONS

Tapered shims were added to the Flight Unit 1 assembly (GE Dwg 47E207100 G3) to correct the damper boom alignment. Revision A of CPD Specification SVS-7314 was issued on 22 September 1966.

4.3 TESTING AND TEST RESULTS

4.3.1 PROTOTYPE NO. 1

Due to the vibration failure of the lamp and solenoid (as discussed in the Eighth Quarterly Report) this unit was disassembled and new lamps and a new solenoid, all of flight quality, were installed. Retesting was completed which included only those tests that were significant as far as performance verification was concerned. All pre-environment functional testing was completed successfully. However, there was some difficulty in performing the eddy current tests in that there appeared to be internal hang-up of the unit. The unit was thoroughly cleaned but to no avail; occasional sticking persisted. The cause of this problem has been determined to be a loose retaining ring that is used as a backup retaining device of the bonded in place pyrolytic graphite rings. This was discovered during post-vibration problems on Engineering Unit 2 (see Section 4.3.2). A re-examination of Prototype No. 1 showed that the retaining ring had dislodged from the seat and was dragging on the magnet mounting plate. The unit was revibrated and the solenoid and lamps passed all tests; however, a new failure occurred. This was a complete fracture of the torsional restraint magnet mounting brackets at the attachment to the primary weldement (see Section 4.4.3 and Figure 4-1). A recheck of Engineering Unit 1 showed a hairline fracture started in the same area. It was therefore decided to terminate all further testing on this unit and use Engineering Unit 2 as a qualification unit.

After the bracket failure the unit was completely disassembled and all structural members were X-rayed and zygloed but no evidence of any structural defects was found.

During the second vibration run, it was noted that the solenoid switch actuating arm had again rotated. This rotation was due to an oversight during the rebuilding of the CPD after the first tear-down in which a nylon tip set screw was to have been replaced with a cup-point set screw. This replacement was made on Engineering Unit 2 and on all flight units.

4.3.2 ENGINEERING UNIT 2

This unit has been used to qualify the redesigned areas on Prototype 1. Redesigned torsional restraint magnet mounting brackets were installed in the unit and one CML (Chicago Miniature Lamp) lamp in the angle indicator was replaced with a lamp from Los Angeles Miniature Products, Incorporated, in order to get increased information on the backup vendor's design. A cup-point set screw was used in the solenoid switch arm assembly replacing the nylon tipped screw previously used.

Functional tests were performed prior to vibration. The unit was then vibrated and accelerated to qual levels. Post-vibration tests were attempted but they were stopped due to internal stickiness. The outer cover was removed and it was observed that the retaining ring used as a backup to the bonded in place pyrolytic graphite had become loose and was causing the drag. This problem was also attributed to the test problems in Prototype 1 and Engineering Unit 1.

The upper magnet mounting plate was removed and the retaining ring was bonded in place. Functional tests were performed and the unit was vibrated again to the qual levels. A post-vibration functional test verified the adequacy of the bonding technique.

The unit was then dismantled for inspection of all of the redesigned areas. The retaining ring was found to be firmly in place; the torsional restraint magnet brackets were removed and X-rayed and zygloed. No degradation was observed. Both lamps functioned normally and the solenoid switch arm had not moved.

4.3.3 FLIGHT UNIT NO. 1

This unit has completed the entire acceptance test program successfully. One minor problem was encountered because of a failure of the Hi-pot test equipment; instead of the 200 vac called for, the equipment output was 1300 volts. Electrical retest of the unit with proper equipment showed no damage to the unit. A temperature sensor was replaced due to an out-of-spec reading. It is not known whether the Hi-pot overstress or the physical damage due to improper handling caused the problem.

This unit has all of the redesigns incorporated, i.e., redesigned torsional restraint magnet brackets, bonded-in retaining rings, and a cup point set screw on the solenoid switch arm.

4.4 FAILURE ANALYSIS EFFORT

4.4.1 TORSIONAL RESTRAINT MAGNET MOUNTING BRACKET

The failure of this part during the second qual vibration test of Prototype 1 was determined to be caused by the sharp corner at the interface of the mounting flange and the arm for the magnets (see Figure 4-1). Analysis of the new bracket shows it to be more than adequate. A large radius was added in the corner and the web thickness increased from 0.080 to 0.125 inch. The first new brackets were installed on Engineering Unit 2 and they have passed two qual vibration tests. X-ray and zyglo inspection after vibration test showed no degradation. New brackets have been installed in all flight units.

4.4.2 SET SCREW

The nylon tip set screw was inadequate to hold the solenoid switch arm in place. The screw was replaced on Engineering Unit 2 with a cup point and passed two qual vibration tests. All flight units have had this design change incorporated.

4.4.3 RETAINING RING

The ring apparently was not firm enough to hold in place during vibration. One ring on Engineering Unit 2 was bonded in place and passed the qual vibration test. Both rings on all flights units are bonded in place.

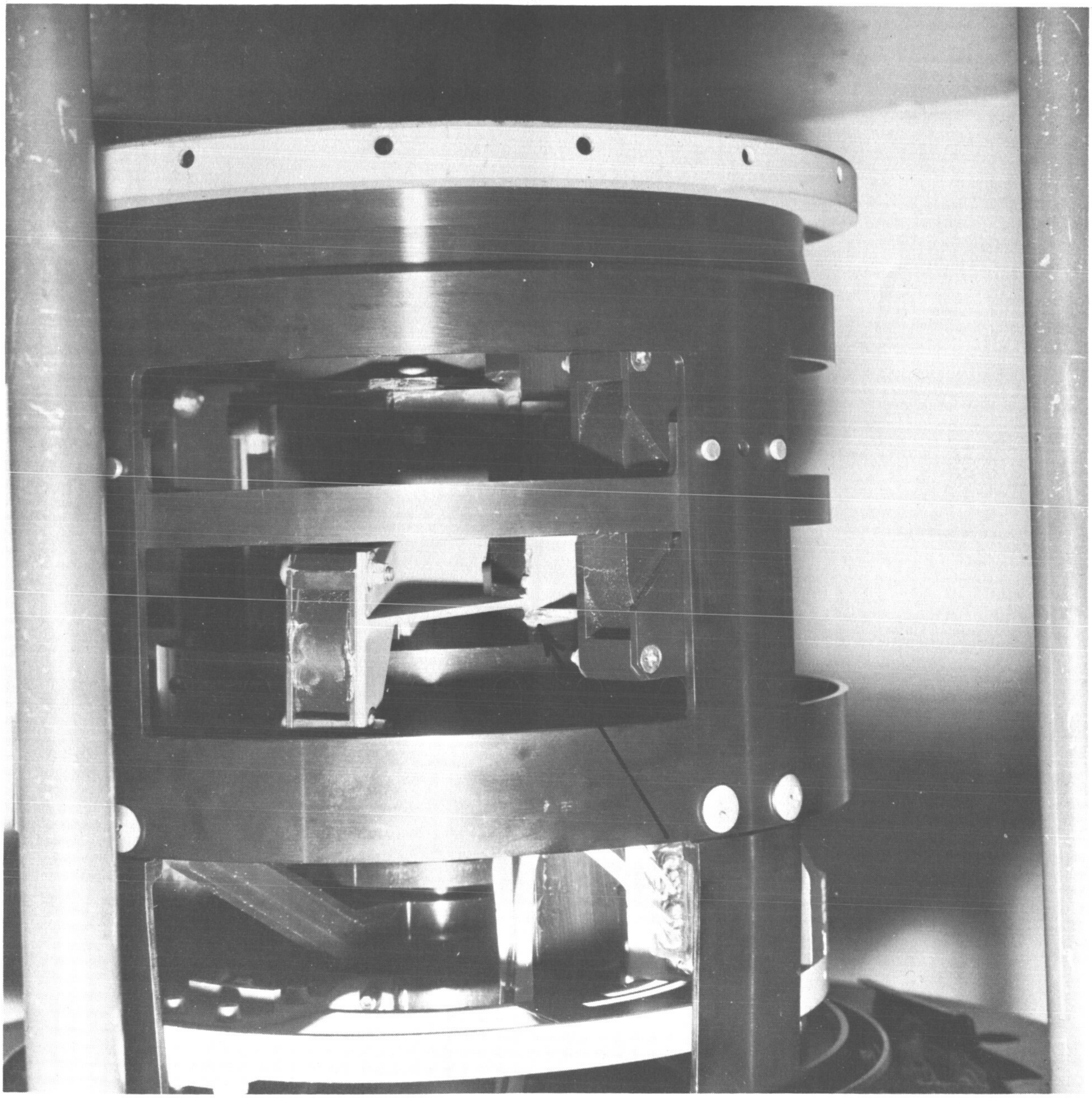


Figure 4-1. Failed Torsional Restraint Magnet Bracket-Quadrant II

SECTION 5

ATTITUDE SENSOR SUBSYSTEM

5.1 TV CAMERA SUBSYSTEM

5.1.1 ENGINEERING UNITS

Specifications and drawings of the TVCS were revised and reissued to reflect the latest TVCS configuration.

The life testing of two of the engineering cameras, (No. 5101 and No. 5102) continued throughout the quarter. Serial No. 5101 video degraded so as to render it useless after 1573.5 hours, not including 200 hours accumulated running time prior to the beginning of the life test. The unit was opened and the focus potentiometer was readjusted. The unit is presently being used in a special dipole investigation test; it had accumulated 2509 hours through the end of this reporting period including 200 "ON-OFF" cycles.

Serial No. 5102 acquired a shorted video output transistor, causing complete loss of video, at 386.7 hours of operating time on life test. (This does not include an approximate 200 hours operating time accumulated on the unit prior to the beginning of the life test.) The transistor was replaced and the life test resumed. Through this reporting period, the TVCS Serial No. 5102 accumulated 1665 hours of life test operating time, including approximately 250 "ON-OFF" cycles.

TVCS Serial No. 5102 was modified to enable testing of a shutter circuit modification which provided a 25 milliamp drive current to the shutter motor rather than a current of 12 milliamps. The shutter was actuated approximately 1200 times with no noticeable mechanical or electrical degradation. This design change will be incorporated into all flight units.

Engineering Unit Serial No. 5103, which was originally designated as the life test unit, has been used to investigate design changes, for miscellaneous troubleshooting, and for accumulated tip target position data. The TVCS was used to view tip targets, under various lighting conditions on the roof of the GE Space Technology Center.

Tip targets of a near prime configuration were placed 132 feet from the TVCS at a 25° angle to the TVCS line of sight. The targets were viewed on a monitor under various lighting conditions. During these tests, photographs of the monitor were taken for each of 6 different lighting conditions, with the targets in each of 20 positions. This series of 120 photos was given to the GE Data Analysis and Evaluation group for interpretation. The tip targets were moved in 6-inch increments in both horizontal and vertical directions, 10 positions horizontal and 10 positions vertical, during each lighting sequence. The lighting used was natural sunlight during the day photo series. Pictures were taken with both black and white backgrounds with the targets sunlighted from both the front and rear. Photos were also taken at night, illuminating the target, from both the front and rear, with a 150-watt flood lamp.

The monitor and the photographic camera settings were varied during the testing series to obtain the best set of conditions (both monitor and photographic camera) for interpreting the photos. The photos are presently being reviewed and report will be issued by Data Reduction and Analysis on the quality of these photos.

5.1.2 COMPONENT QUALIFICATION UNIT

The component qualification unit was received from the vendor during the past quarter; following is a summary of the work performed.

5.1.2.1 TVCS No. 5104

The Burn-in test was completed and it revealed potentiometer problems. The potentiometers used in the focus adjust, target voltage adjust, and beam current adjust circuits were replaced with a higher quality potentiometer; this was also done on all flight units. The potentiometers initially used shifted or opened causing the video to become unusable. The burn-in test also revealed shutter problems which seemed to be caused by poor workmanship. All shutter mechanisms were therefore reworked and more closely inspected. TVCS No. 5104 then passed the functional test with the exception of the sun sensor angle sensitivity test.

The sun sensor sensitivity potentiometer was incorrectly set at the vendor's facility. This potentiometer was readjusted and the unit performed properly. After repair and readjustment of the TVCS, it passed the following tests: functional, humidity, and functional. During the vibration test, the control unit failed when 3 capacitors broke loose from the boards and the crystal became noisy. Spots also appeared on the camera vidicon. The control unit problems were solved by properly conformal coating all components in place; the crystal problem was solved by adding an O-ring between the cover and base of the control unit to provide a small amount of damping between the control unit base and all parts attached to it. The vidicon spots appear to have been caused by contamination inside the vidicon; they became somewhat noticeable after the loose particle detection test. It was decided to continue testing with this vidicon since no spare was available for qualification use.

The control unit passed the fourth vibration test after all rework had been completed. All rework items were incorporated into all flight units once they were proven valid in the qualification unit. This unit was then subjected to the following tests: temperature storage, functional, thermal-vacuum, and functional; the unit passed all of these tests. TVCS 5104 must still be subjected to another vibration test (camera only) since some small amount of rework on the shutter was performed and since the bracket installation technique was slightly modified. This vibration test on the camera only will prove the validity of the two items. When this test has been completed, the qualification program will be completed.

5.1.3 FLIGHT UNITS

Four flight TVCS units were received from Lear Siegler during the reporting period; following is a summary of the work performed.

5.1.3.1 TVCS No. 5108 - Earth Pointing Flight Unit

This unit was received at GE on 15 July 1966 and the burn-in test was performed. After burn-in, the three previously mentioned potentiometers (focus adjust, target voltage adjust, and beam current adjust) were replaced and the shutter was reworked.

The control unit was also reconformal coated to prevent mechanical damage to parts during the vibration testing. The sun shutter potentiometer was readjusted. The unit then passed the functional test, but failed the vibration test. The shutter opened and the camera brackets became loose. The bracket installation procedure was changed to prevent improper installation. The brackets were reinstalled and the shutter motor was reworked. The unit then passed vibration (camera only). While in the thermal-vacuum chamber, the shutter would not consistently open when commanded and the video defocused, both at low temperature. The shutter motor was replaced and the control unit was readjusted to provide a better video. The unit then passed the following tests: functional vibration, and functional. During the cold cycle in the thermal-vacuum chamber, the shutter again failed to open consistently. The test was halted and troubleshooting of the cause for this malfunction was begun.

5.1.3.2 TVCS No. 5107-Sky Pointing Flight Unit

Camera systems 5107 and 5110 comprise Flight Unit No. 1. The 5107 unit was received by GE on 13 July and the burn-in test was completed with no outstanding problems encountered. The three potentiometers previously mentioned were replaced and the unit was reconformal coated to maintain control of the configuration. The unit passed the initial functional test after readjusting the sun sensor sensitivity potentiometer; however, the lens assembly fell apart during the vibration test. The unit was returned to the vendor for repair (lens assembly not properly assembled) and it was returned to GE. It then passed functional, vibration, and functional testing.

During the thermal-vacuum test, the window became contaminated at low temperature and the test was halted. An analysis of the contamination revealed it to be caused by Loc-Tite (from the window support screws); an excessive amount was used. The unit was cleaned and reassembled and, during the setup for the thermal-vacuum test, the video signal was lost. The unit will be repaired by the vendor at GE; testing will resume at the beginning of the acceptance cycle.

5.1.3.3 TVCS No. 5109 - Earth Pointing Flight Unit

This unit was received by GE on 16 September and the burn-in test was performed. No serious problems have been revealed through the first hot/cold cycle.

5.1.3.4 TVCS No. 5110 - Earth Pointing Flight Unit

Camera systems 5110 and 5107 comprise Flight Unit No. 1. TVCS 5110 was received by GE on 30 September. It was initially subjected to a burn-in test and exposed to the acceptance tests that included: functional vibration, functional, thermal-vacuum, and a final functional test. This unit was tested for compatibility with the 5107 unit and these first units were shipped to HAC on 29 October.

5.2 SOLAR ASPECT SENSOR

5.2.1 ANALYSIS OF FLIGHT ANOMALY EXPERIENCED ON THE GGTS VEHICLE

A solar aspect system very similar to the one used on the ATS-A and ATS-D/E flight was incorporated on the Gravity Gradient Test Satellite. The system operated properly except in the transition area of Detector Heads 4 and 5.

Shown in Figure 5-1 is a plot of the sensor output and the eye identification versus time for Detector Heads 4 and 5. Whenever Head 4 was selected by the electronics as the most illuminated and the sun had not come into the field of view of Head 5, the data was valid. The same was true whenever Head 5 was selected by the electronics as the most illuminated head.

Thus, the band of uncertainty was narrowed to those periods when a head was selected and the sun was also in the field of view of Head 5.

Figure 5-2 is a block diagram of the solar aspect sensor subsystem. Upon the receipt of a start pulse, the data register and identification register are cleared and the A1 flipflop is set in the "one" state. The A1 flipflop is used to control the 4 kc clock pulse generator and the eye selection switches. Clock pulses cause the identification counters S1, S2 and S3 to count. The outputs of these counters are decoded as shown in the block diagram and thus provide the scan system to select the most illuminated head. When the most illuminated head is selected, the current produced by the AGC cell will flow into the grounded base amplifier and cause a pulse to occur at the differential amplifier.

The A2 flipflop was set to the "one" state when S1 changed state. In the "one" state, the A2 flipflop enables the threshold switch.

The pulse produced by the differential amplifier when the proper head is scanned caused the threshold detector switch to close. The negative going step voltage produced by the threshold switch causes the 500 μ s monostable multivibrator to be triggered.

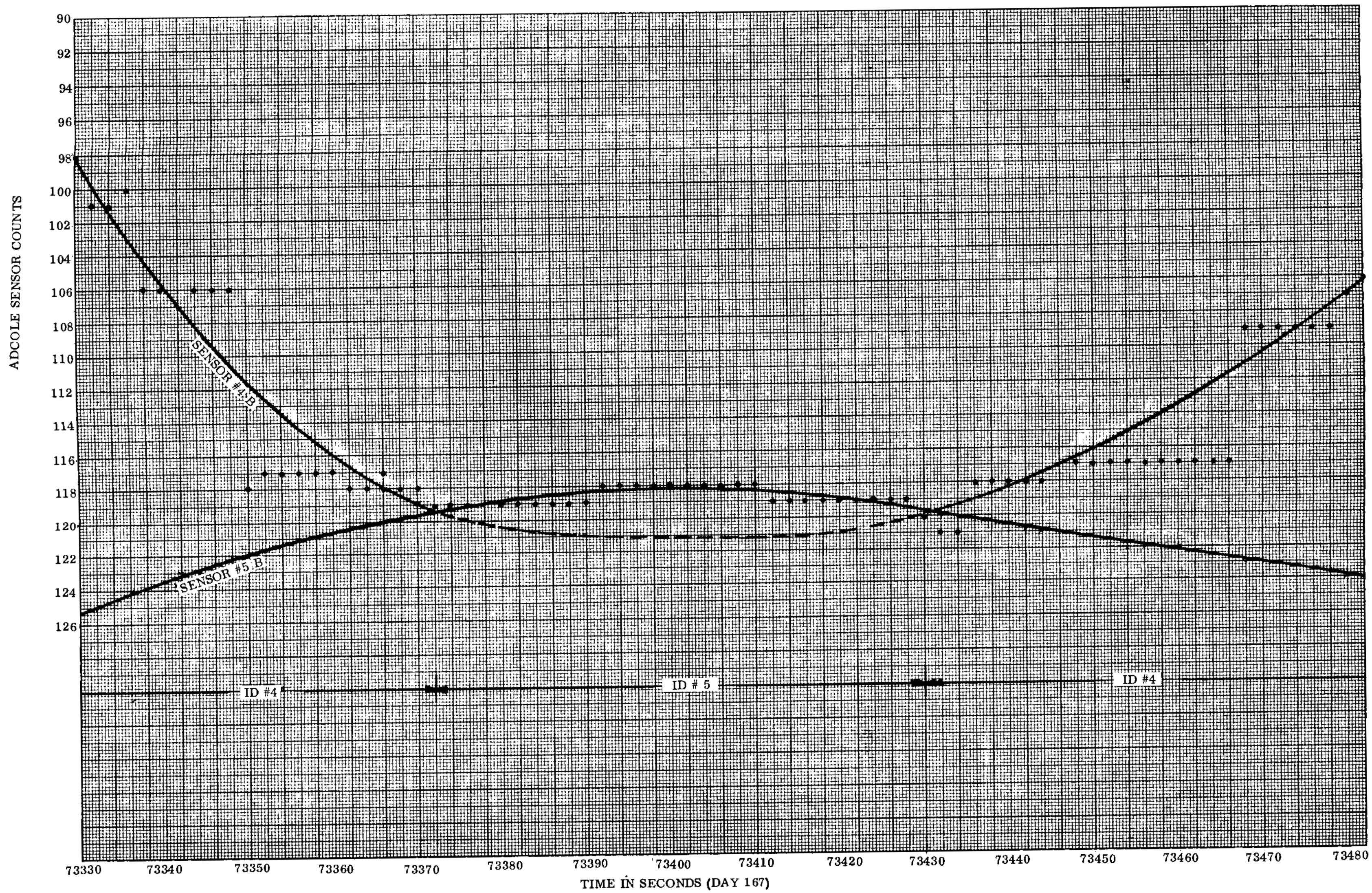


Figure 5-1. Solar Aspect Output Versus Time for Detector Heads 4 and 5

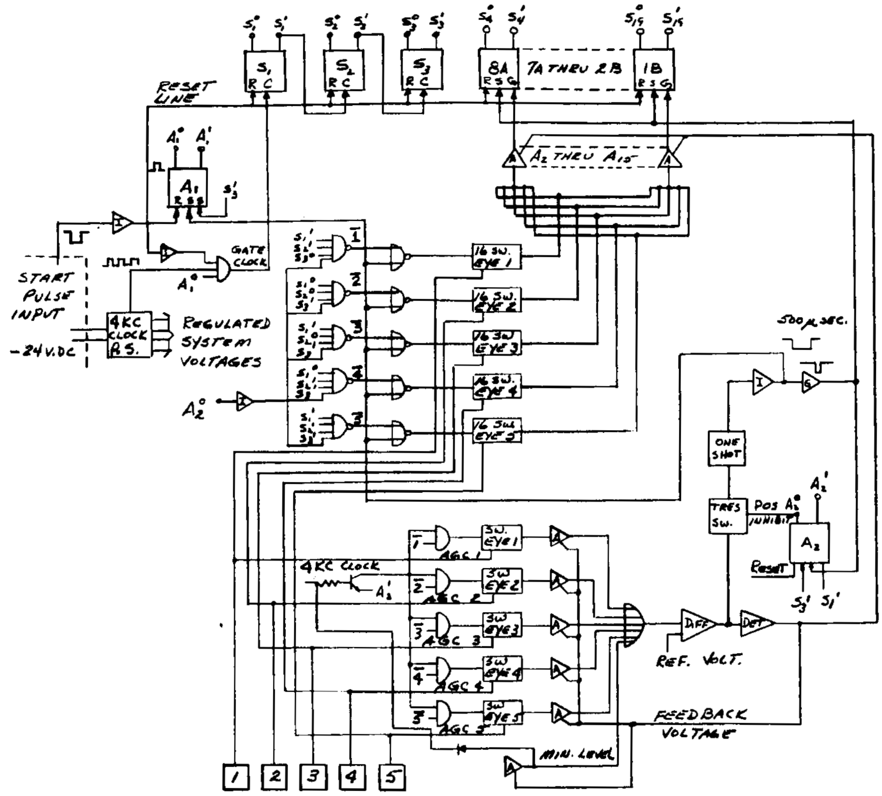


Figure 5-2. Solar Aspect Sensor Logic

The output of the one-shot is inverted and used to drive the NOR gate inputs. This ground level, together with the ground level input of the decoded identification, will cause the series switches of the selected head to close. Current from the solar cells of the selected head will flow through the correct data register amplifier.

Considering the symptom of the anomaly that whenever Head 5 could see the sun but not be selected as the most illuminated, the data became erroneous, leads to the conclusion that the circuitry pertaining to Detector 5 is always enabled. Referring to the block diagram (Figure 5-2) if the NOR gate to series switches of Head 5 had an open input, the switch would remain closed and pass any information from Head 5 regardless of what head was selected.

A section of the GGTS data of Day 167 from 73, 330 seconds to 73, 480 seconds was analyzed with the assumption that this data was received from two detectors.

A plot was made of the field of view of Detector 4 and Detector 5 and transferred to one graph as shown in Figure 5-3. The graph starts where Head 5 begins to see the sun but Head 4 is the most illuminated. By combining the Gray Code outputs of both detectors, a third plot was made as shown by the small dots. The combined plot was then compared to the actual flight data and was found to be identical.

Although the system has malfunctioned and the data erroneous, meaningful information can be derived by the same technique used on the graph.

5.2.2 COMPONENT STATUS

The Engineering Unit (EU-1) had completed all tests and evaluation in December 1965. The Qualification Unit(PO-3) and Prototype Unit (PO-2) were completed and accepted by August 1966.

The ATS Flight A had completed acceptance tests in late August 1966. Acceptance tests on Flight D hardware are currently in progress and expect completion in mid-November 1966. Flight E is expected to be completed in December 1966.

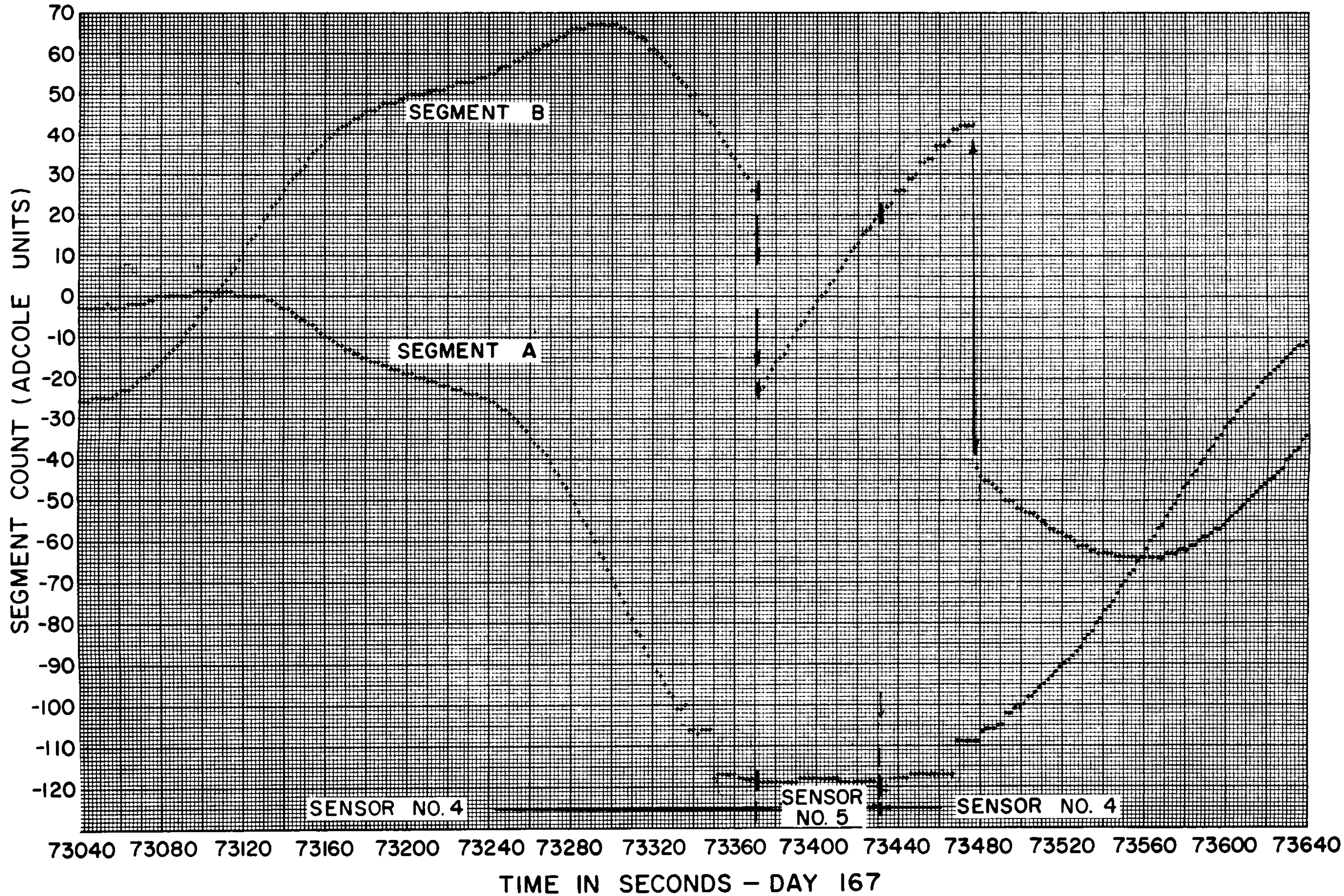


Figure 5-3. SAS Detector Data (GGTS Flight for Day 167)

5.3 POWER CONTROL UNIT

5.3.1 TRANSIENT INVESTIGATION

During the system testing of the Power Control Unit at Hughes, it was discovered that when the system was energized the -30 volt current limiter would be turned-off. Upon investigation, the cause of the problem was traced to turn-on of the squib circuits. It was observed that all squibs would draw current for 15 microseconds resulting in a total of at least 15 amperes (depending upon the load). The high current would cause the regulator to turn-off.

Subsequent investigation of this problem at GE led to the following methods of either reducing or eliminating the problem.

a. Addition of filtering in the -30 volt line.

b. Addition of a capacitor in the squib driver output storage

The second method was chosen because it alleviated the problem and had the least effect on the schedule.

The Qualification Unit (Prototype 1) was modified and retested at General Electric. Upon successful completion of the test, the unit was shipped to HAC for a system compatibility test. The system test proved that the addition of the capacitor eliminated the turn-off problem. All flight units were then modified by addition of a capacitor in the squib driver output stage.

5.3.2 PRIMARY BOOM PYROTECHNIC UNCAGING

Neither of the two approaches mentioned on page 5-13 of the Eighth Quarterly Report were used for uncaging the Primary Boom by pyrotechnics as both methods required extensive rework thus causing a long schedule delay.

A decision resulting in the removal of the clutching capability in the Primary Boom (as discussed on page 3-4 of the Eighth Quarterly Report) made available four solenoid driver circuits in the Power Control Unit. The four solenoid driver circuits are now being used to actuate four squibs, two in each Primary Boom. These driver circuits have the capability of driving loads of 5 amperes maximum. As the squib required 3 amperes minimum for sure-fire, 5 amperes was sufficient. Current-limiting resistors were installed in the Primary Boom in order to prevent the current from exceeding 5 amperes.

A test was performed on 10 of these transistors to determine pulse current capabilities. The test proved encouraging; it was found that a current as high as 10 amperes for a duration of 100 milliseconds would not cause a breakdown in the transistor. The tests were run to determine the capability of the transistors to withstand collector current and power dissipation in excess of the manufacturer's ratings.

The circuit used for this investigation was identical to those used in the Power Control Unit. Driving the power circuit was a monostable multivibrator with a period of 33 seconds, and a 100 millisecond wide pulse. The power circuit output had a high wattage, variable resistance load.

Ten transistors were selected for this test; five were commercial parts, and five were prime parts. Each transistor was pulsed a minimum of 50 times with loads of 5 amperes to 7.5 amperes in 1/2 ampere steps. Five transistors were then selected for further evaluation up to 10 amperes. At the start, middle, and end of the test, V_{ce} and current were monitored and recorded. (See Table 5-1.) The analysis (Table 5-2) shows very little deterioration in the transistors due to this test.

5.3.3 PROTOTYPE POWER CONTROL UNIT

5.3.3.1 Prototype Unit 1

This unit was delivered to Hughes for a system test. When the noise problem developed, it was returned to General Electric for modification to the squib driver circuits. After modification, the unit was functionally tested. Based upon the test result, the unit was then released for shipment to Hughes. The unit successfully passed the systems test and no problems were encountered during power turn-on.

5.3.3.2 Prototype Unit 2

This unit was not returned to General Electric for modification and is at Hughes undergoing system compatibility testing.

5.3.4 FLIGHT POWER CONTROL UNITS

5.3.4.1 Flight Unit 1

Capacitors were installed in the squib circuits and the unit was assembled. An in-process test was performed, the unit was conformal coated, and subjected to an acceptance test. Upon successful completion of the acceptance test, a systems test was performed further proving a complete compatibility of the unit. Flight Unit 1 was shipped to HAC on 22 October.

5.3.4.2 Flight Unit 2

Capacitors were installed in the squib circuit of the second flight unit PCU. An in-process test was conducted during assembly. The unit was conformal coated and subjected to the acceptance tests. Testing was completed during the week of 26 September and this unit was prepared for bonded storage at GE.

5.3.4.3 Flight Unit 3

Assembly of the third PCU flight unit was completed during the early part of October, and it successfully passed the acceptance tests. It will be stored at GE for shipment at a later date.

Table 5-1. Power Stress Test Results (V_{ce} After 50 Pulses)

Current (Amperes)	V_{ce} Sat (Volts)									
	Commercial Parts					Prime Parts				
	A	B	C	D	E	F	G	H	I	J
5.0	1.6	1.2	1.0	1.2	1.2	1.4	1.3	1.3	1.3	1.2
5.5	1.3	1.2	1.0	1.0	1.2	1.4	1.2	1.2	1.0	1.5
6.0	1.3	1.4	1.2	1.2	1.4	1.4	1.6	1.3	1.3	1.5
6.5	1.6	1.4	1.3	1.3	1.5	1.5	1.8	1.4	1.3	1.5
7.0	1.7	1.7	1.3	1.5	1.5	1.6	2.0	1.6	1.5	1.7
7.5	1.7	2.0	1.4	1.5	1.7	2.0	2.2	1.7	1.7	1.7
8.0	2.2		4.0		4.0		4.2		2.2	2.5
8.5	2.6		5.5		4.8		5.5		3.8	3.0
9.0	2.5		5.8		6.0		6.0		3.5	3.1
9.5	3.2		6.2		6.2		6.2		3.8	3.5
10.0	4.0		7.0		7.6		7.5		4.2	4.8
10.5	5.5									
11.0	5.5									
11.5	6.0									

Table 5-2. Prime Part Test Results

Prime Part	I_{ce} (NA) 2/12/66	I_{ce} (NA) 9/22/66	h_{fe} (NA) 2/12/66	h_{fe} (NA) 9/22/66
F	0.46	1.0	86	87
G	0.40	1.0	87	90
H	0.09	1.0	89	89
I	0.32	1.0	88	89
J	0.40	1.0	83	90

I_{ce} at V_{ce} = 60 vdc and V_{be} = - 2 vdc

H_{fe} at V_{ce} = 2 vdc

I_{ce} = 1 amp dc

SECTION 6

GROUND TESTING

6.1 ENGINEERING EVALUATION TESTS

During the past quarter, component engineering testing was limited to the areas described in Sections 6.1.1 through 6.1.6.

6.1.1 PRIMARY BOOMS

Tests involving the Primary Boom Engineering Units have been completed.

6.1.2 DAMPER BOOM

Tests using the Damper Boom Engineering Unit have been completed.

6.1.3 TV CAMERA

Life test of Engineering Unit camera 5101, which was begun during the last quarter, was continued. The camera accumulated more than 2500 hours through the end of this reporting period, which included 200 on-off cycles. A similar life test of TVCS 5102 was begun with an accumulation of 1665 hours to date, including 250 on-off cycles. Engineering Unit 5103 has been used as a test bed for investigation of design changes, miscellaneous trouble-shooting, and to acquire TV target position data in tests on the roof of the GE Space Technology Center. These activities are reported in detail in Section 5.1.

6.1.4 POWER CONTROL UNIT

Tests involving the PCU Engineering Unit have been completed.

6.1.5 SOLAR ASPECT SENSOR

All scheduled testing with the use of the Engineering Unit SAS has been completed.

6.1.6 COMBINATION PASSIVE DAMPER

Vibration and acceleration tests on the Engineering Unit No. 2 CPD were conducted. See Section 4 for detailed test results.

6.2 COMPONENT QUALIFICATION

Test instructions have been completed for qualification and acceptance testing of the ATS components. Table 6-1 summarizes the test procedure activity during the past quarter.

Table 6-1. Qualification Test Instructions*

Component	Document Available	ITPB Review	NASA Approval
Solar Aspect Sensor	1/19/66	2/15/66	4/20/66
TV Camera	2/3/66	3/16/66	4/20/66
Combination Passive Damper	2/25/66	3/24/66	4/20/66
Power Control Unit	2/7/66	2/25/66	4/20/66
Damper Boom	2/14/66	3/29/66	4/20/66
Primary Boom	Estimated 7/25/66	8/1/66	9/2/66

*Also applicable to flight acceptance test instructions

The component qualification hardware program is summarized in Table 6-2.

Table 6-2. Qualification Program Summary

Component	Qualification Status	Remarks
PCU	Test Completed	Test Report No. 4315-QC-003 issued 7/14/66
Damper Boom	Test Completed	Test Report in process.
CPD	Test Completed	Test Report in process.
SAS	Test Completed	Test Report 4315-QC-007 issued 8/31/66.
TV Camera	Test Completed	Test Report in process.
Primary Booms	Tests in Process	See Section 3 for problem discussion.

6.3 SYSTEM QUALIFICATION

The system performance test on the prototype spacecraft was completed on 10 September 1966. All of the GE gravity gradient components were successfully operated. On 15 October 1966, the vibration test was completed. All axes in both random and sine modes were accomplished. A successful post-vibration performance test was completed on 18 October 1966.

The thermal-vacuum test was started on 29 October; however, due to a co-contractor component problem, the test was aborted on 2 November 1966. The thermal-vacuum test was continued on 8 November 1966 after a successful GE gravity gradient checkout.

6.4 FLIGHT ACCEPTANCE AND AGE

6.4.1 STATUS

All flight acceptance test instructions have been approved by NASA/GSFC. The document number (Standing Instructions) and NASA approval dates are:

	SI	NASA Approval Date
Primary Booms	237,037	9/2/66
Damper Boom	*DHC-SP-ST.110M	4/20/66
CPD	237,016	4/20/66
TV Camera	237,013	4/20/66
SAS	237,012	4/20/66
PCU	237,015	4/20/66

*deHavilland document

With the exception of the Primary Booms, all Flight A hardware compatibility tests have been completed with the Hughes Experimenters' Console (EPC). A telemetry short was uncovered in the electronics unit of TV Camera No. 2 during this checkout. The TV subsystem was shipped to Lear-Siegler for repair.

6.5 QUALIFICATION TESTING

6.5.1 PARTS QUALIFICATION

The ATS Parts Qualification Program was completed during the reporting period. Table 6-3 lists the items that comprise the program.

Table 6-3. Identification of Items in Parts Qualification Program

PART	IDENTIFICATION NUMBER	VENDOR	TEST PLAN	STATUS OF WORK	NO. OF PARTS TESTED	DISPOSITION
GROUP A						
Transformer, Inverter	R4610P1	EG&G	Assoc. Testing Labs. Test Procedure TP-2589-11	Complete	5	Qualified
Solar Cell Assy.	R4611P1	Hoffman	Assoc. Testing Labs. Test Procedure TP-2662-11	Complete	5	Qualified
Two-Way Solenoid	R4612P1	Koontz-Wagner	Koontz-Wagner T.P. KES-0241	Complete	6	Qualified
Cable Cutter Assy.	115C7516P1 895D724P1	Holex	Table I of GE Spec. SVS5292	Complete	20	Qualified
Extension Motor	106A161	Globe Ind.	GE Test Plan ETP-4165-2	Complete	2	Qualified
Scissor Motor	114A152	Globe Ind.	GE Test Plane ETP-4165-3	Complete	2	Qualified
Linear Actuator Assy.	47C209587G1	Holex	Table I of GE Spec. SVS7428	Complete	18	Qualified
Lamp	47C207314P1	Chicago Min.	GE Test Plan ETP-4165-1	Cancelled	-	Cancelled
Lamp	47C207314P1	Lamps, Inc.	GE Test Plan ETP-4382-6	Cancelled	-	Cancelled
Damper Boom Release Assy.	47D209597	(see test plan)	GE Test Plan 4182-SPTP-0016	Complete	(see test plan)	Qualified
GROUP B						
Transistor	R4343P1 (2N2432)	Texas Instr.	GE PIR 4493-033	Complete	5	Qualified
Relay	R2313P11	GE	GE PIR 4494-057	Complete	5	Qualified

SECTION 7
QUALITY CONTROL

7.1 PRIMARY BOOMS

QC Engineering Test Reports 4315-QC-016 and 54315-QC-017 were issued pertaining to the acceptance tests performed on the two Systems Qualification Dampers, S/N 11 and 12.

Supplement 1 to Failure Analysis Report 223-E-14 was issued which pertains to the machine finish that caused uncaging difficulty on S/N 11.

Standing Instruction 237, 036, Qualification and Acceptance Test Procedure for Primary Booms was issued. The SI was further amended to require that an engineer witness all caging, uncaging, extension, and retraction of the primary booms since these operations are most critical.

Qualification testing of Component Qualification Boom System (S/N 100) continued during the reporting period. Several failures such as sheared pins, leaks, bearings, and uncaging occurred. Testing was discontinued after thermal-vacuum environment, and the component was subjected to a series of uncaging tests. A failure analysis and retest matrix was developed. It was determined that leakage was evident at a connector. The unit was then returned to deHavilland for investigation and resolution of the bearing failure which is now underway. Humidity tests were conducted on primary booms, TV tip targets, and gear lock assembly as part of the qualification test program. Supplement No. 1 to Failure Analysis Report 224-E-15 pertaining to oversize screw heads that caused sheared roll pins in the transmission unit was issued. Corrective action was taken at deHavilland.

Acceptance testing of the Flight 1 units began during the period. Each unit has experienced several failures such as sheared roll pins, back winding of boom element, uncaging problems, beaming failures, etc. Both units (S/N 101 and 10) were returned to deHavilland where they were reworked and returned to GE. Each unit is now in its acceptance test cycle. The following failure analysis reports were issued:

F.A.R. 249-E-25 pertains to S/N 10 uncaging problems during thermal-vacuum testing. This report concluded that test equipment and test setup prevented uncaging.

F.A.R. 256-E-27 pertains to the S/N 10 motor becoming sluggish, then stopping during retraction test. This failure was attributed to bearing misalignment.

F.A.R. 255-E-26 pertains to uncaging problems on S/N 101 during thermal-vacuum testing. As noted above, the failure was attributed to test equipment and test setup.

Supplement No. 1 to F.A.R. 247-E-23 pertains to systems test failure on S/N 101. This report outlined the corrective action taken at systems test to prevent damage of a unit due to a faulty test setup.

A series of armature current traces taken on both extension and scissors motors of S/N 100, 101 and 10 revealed that each motor is functioning properly.

Due to bearing failures and sheared pins in the transmission unit, it was necessary for GE Engineering to redesign the transmission enclosure. Product Assurance conducted a series of leak tests to evaluate the redesign.

7.2 DAMPER BOOM

QC Engineering Test Report 4315-QC-005 pertaining to acceptance test on the Systems Qualification Unit S/N 10 was issued.

Acceptance testing of the Flight 1 Damper Boom was completed at GE instead of deHavilland. One problem pertaining to rewind of the unit was noted. Supplement No. 1 to Failure Analysis Report 229-E-18 outlining the corrective actions taken to eliminate the rewind problem was issued. The Damper Boom was mated to the CPD and delivered to the spacecraft contractor.

The Prototype S/N 11 Damper Boom qualification test cycle is complete and the unit in use as a test bed for several additional tests. Hot and cold deployments will be conducted. An additional alignment test was conducted and additional vibration tests are underway to determine if spool loss of torque during vibration environment could result in a tape cracking failure. Failure Analysis Report 228-E-17 (pertaining to torn tape, tape doublers, failure to extend, etc., that occurred during the qualification cycle) was issued. This report established seven corrective action items to be accomplished at GE and deHavilland. See Section 3.4.2.

7.3 COMBINATION PASSIVE DAMPER

Qualification testing of Prototype 1 was discontinued after failure of a torsional restraint bracket and a loose retaining ring during the vibration environment. Testing was discontinued because of the possible fatigue factor since the structure had been subjected to several qualification level vibration tests. Design changes required as a result of the failures were incorporated into Engineering Unit 2. This unit was then subjected to qualification level tests where the design changes were proven and additional data to supplement Flights ATS-D/E were compiled. A complete test matrix pertaining to the qualification test program of the CPD was prepared and discussed with NASA on a trip to Goddard.

Seventeen major structural parts from the Prototype 1 CPD were subjected to X-ray and zyglo inspection after qualification tests were discontinued. No defects or degradation was noticed.

Acceptance testing of Flight 1 was completed and the unit was delivered to the spacecraft contractor. During the test sequence, two significant deviations were noted. During Hi-pot testing, 1300 volts were applied to the unit instead of 200 volts and a loss of eddy current damping was noted after vibration. Each deviation was attributed to test equipment. Failure Analysis Report 237-E-20 pertaining to the Hi-pot test, and Failure Analysis Report 257-E-28 pertaining to the loss of eddy current damping were issued. The five day preliminary acceptance test report on the unit was issued by QC Engineering.

A series of hot and cold performance tests was deleted from the component specification and standing instruction after approval was received from the customer.

Continuous investigations are being conducted by Engineering and Manufacturing along with Product Assurance to determine means and methods of eliminating magnetic contamination during assembly and testing.

7.4 TELEVISION CAMERA SYSTEMS

Qualification testing of S/N 5104 was completed during this period. All data is being reviewed by Product Assurance and Design Engineering. Preparation of the Qualification test report is in progress.

Acceptance test of S/N 5107 and 5110 Flight 1 Systems were completed, and the units were delivered to the spacecraft contractor.

Camera System S/N 5109 failed during acceptance test. It was returned to LSI where it was found that a frayed wire and bad vidicon socket caused the intermittent video problem during test. The unit was reworked and returned to GE; acceptance test of this unit is now in progress.

Camera System S/N 5108 failed during acceptance test. Failure Analysis Report 262-E-29 pertaining to defocussing, poor resolution, and blurring of the picture which caused the failure was issued. This report concluded that surplus Loc-tite caused contamination during thermal-vacuum environment. The camera was reworked and is now in its acceptance test cycle.

Flight unit camera systems underwent a 72-hour thermal-vacuum (burn-in) test in advance of acceptance tests. The burn-in is to screen out any faulty parts. LSI representatives were on hand to rework and adjust the cameras after the tests.

7.5 SOLAR ASPECT SENSOR

Acceptance test of the Flight 1 SAS was completed and the unit was delivered to the spacecraft contractor. The QC Engineering acceptance test report pertaining to the component was issued.

The Flight 2 SAS failed initial insulation resistance test at GE. It was returned to Adcole who attributed the failure to a thermistor. The unit was reworked and returned to GE. It is now in the acceptance test cycle.

An additional test has been incorporated into the component Standing Instruction to ensure that the intelligence being transmitted is solely from the detector being illuminated.

7.6 POWER CONTROL UNIT

The Flight 1 PCU was delivered to the spacecraft contractor. QC Engineering Test Report 4315-QC-015, pertaining to the acceptance test of the unit, was issued.

Acceptance test of the Flight 2 PCU was completed and QC Engineering Test Report 4315-QC-014 was issued.

Additional testing of the component qualification unit took place to verify results of design changes incorporated into the PCU. The unit successfully passed all retests; Engineering Test Report 4315-QC-011 was issued. The design changes were also incorporated into the flight units. The units passed all tests as noted above.

An additional test was incorporated into the SI to ensure that all straight-through lines in the PCU are electrically isolated from all other lines. In addition, the component SI was revised to incorporate changes to the procedure and data sheets.

Acceptance testing of the Flight 3 PCU is in progress.

Failure Analysis Report 199-E-9 and Supplement No. 1 pertaining to failure of a transistor in a field driver module was issued. Corrective action was taken.

Supplement No. 1 to Failure Analysis Report 244-E-22 outlining the action taken to prevent a recurring failure of a Reset Buffer Module was issued.

7.7 SYSTEMS TESTS

Systems tests on GE-AGE for first flight units were deleted. Each component will be tested at Hughes Aircraft on Hughes experimental package console.

Systems tests on ATS-D flight components will be conducted at GE in July 1967 while systems test on ATS-E flight components will take place at GE in January 1968.

A primary boom squib simulation box and cable assembly were delivered to HAC.

Five actuator squibs were fired at GE using the PCU and systems test console.

A Product Assurance Systems Test Representative is at Hughes Aircraft to operate GE components during systems test.

7.8 PARTS QUALIFICATION

The second revision to the qualification test report on primary boom extension and gear head motors was issued.

7.9 GENERAL

Hi-pot testing was deleted from the test procedure for all ATS components after approval was received from NASA.

SECTION 8

MATERIALS AND PROCESSES

8.1 PRIMARY BOOMS

A failure analysis of the primary boom pyrotechnic release mechanism showed no dimensional interference or malfunction of the part. This analysis was conducted after the primary boom failed to uncage after firing one linear actuator squib but did uncage after the second was fired. Metallographic analysis of the shear surface of the pin showed that a clean fracture had occurred; there was no evidence of the pin having been struck twice.

The following reflectance values were obtained on samples cut from the Component Qual Primary Booms (S/N 100):

α_s	Reflectance
0.136	0.864
0.138	0.862
0.131	0.869
0.165	0.835
0.140	0.860

8.2 COMBINATION PASSIVE DAMPER

Contamination in the CPD was identified spectrographically as being the same material, Alnico V, as the magnets used in the CPD. Microscopically, the material appeared to be the result of fractures rather than produced by machining. The material is probably from a magnet which became free during vibration testing and was vibrating in the unit.

Seventeen damper boom angle indicator lamps were examined before and after vibration to the requirements of GE Drawing PR47C207314. There was no significant change in the lamps as determined by microscopic examination.

8.3 TV CAMERA

Twenty (TV) tip targets were fabricated. Fabrication consists of applying Eccospheres S1, quartz microballoons from Emerson-Cuming, to one surface of a 1/8 inch thick Lexan polycarbonate target to give a diffuse reflectance coating. Aluminum is then vapor-deposited on the opposite surface at a pressure below 10^{-5} torr. This is then overcoated with silicon dioxide. The Eccosphere coated surface is the one facing the camera. The diffuse reflectance is 30 percent or higher when measured in the wavelength range of 0.35 to 1.0 micron. The total reflectance is greater than 40 and less than 70.

A test of the TV camera shutter lens assembly was run in vacuum at 2×10^{-6} torr. The unit was held at $150^{\circ}F$ for 2-1/2 hours, then at $0^{\circ}F$ for 3-1/2 hours, and followed by 64 hours at $150^{\circ}F$. The shutter operated satisfactorily at all these points and there was no contamination detectable on cooled sodium chloride disks placed near the unit.

The shells of twenty electric connectors, P/N PT 06P-8-4S, were stripped of cadmium plating in nitric acid. They were gold plated over a copper strike and copper plate, and reassembled into the connectors.

SECTION 9

MANUFACTURING

Technical support was provided by the Manufacturing operation during assembly and test of the ATS gravity gradient stabilization system. The manufacturing status of the systems is summarized as follows:

a. Prototype 1

Fabrication of all units comprising the Prototype 1 system is completed. The Primary Boom unit was returned to deHavilland for conversion to the ATS-D/E Configuration.

b. Prototype 2

Fabrication of all components is complete.

c. Flight Units

1. Flight 1 - Except for the Primary Boom system, shipment of Flight 1 hardware is complete.

2. Flight 2 - Except for the Primary Boom, fabrication of Flight 2 hardware is complete.

3. Flight 3 - The CPD is in final assembly. The Primary Boom fabrication is in a hold status. SAS fabrication is in progress.

d. AGE

Fabrication of all AGE has been completed.

e. Test Equipment

Fabrication of all test equipment is complete.

f. Bonded Storage

Plans are being formulated for inventory disposition of the ATS flight equipment in bonded storage at GE.

SECTION 10

RELIABILITY

A reliability analysis was published (PIR's 4341-ATS-11, 19, and 23) on the revised tip mass release circuit (Reference 8th Quarterly Report P3-6). Part stress analyses and failure mode/effects analyses were performed, and the circuit was adjudged satisfactory by Reliability Engineering. The reliability of the revised circuit was assessed at 0.99993.

A final ATS Reliability Report is being prepared, with publication scheduled during the week of 28 November.

SECTION 11

NEW TECHNOLOGIES

There are no new technologies to report for the quarter. Efforts to monitor the analytical and developmental areas will continue, and resulting new technologies will be reported in future reports.

SECTION 12

GLOSSARY

The following is a list of abbreviations and definitions for terms used throughout this report:

ADTF	Advanced Damping Test Fixture (used for CPD testing)
ATS-A	Medium Altitude Gravity Gradient Experiment (6000-nautical mile orbit flight)
ATS-D/E	Synchronous Altitude Gravity Gradient Experiment (24-hour orbit flight)
CPD	Combination Passive Damper
Crab Angle	Out-of-orbit angle flight caused by changes in X-rod angle
DME	Dynamic Mission Equivalent (Accelerated Functional Program)
GE-MSD	General Electric Company Missile and Space Division
GGS/ATS	Gravity Gradient System/Applications Technology Satellite
HAC	Hughes Aircraft Company
ITPB	Integrated Test Program Board
Local Vertical	Imaginary line extending from the satellite center of mass to the center of mass of the earth
LOFF	Low Order Force Fixture (used for CPD testing)
MTBF	Mean Time Before Failure
MTTF	Mean Time to Failure
PCU	Power Control Unit
PIR	Program Information Request/Release, GE documentation
SAS	Solar Aspect Sensor
Scissoring	Changing the angle included between the primary booms in a manner that maintains a symmetrical configuration about the satellite yaw axis
STEM	Storable Tubular Extendable Member
Stiction Torque	That amount of torque required to overcome the initial effects of friction
SVA Fixture	Shock and Vibration Attachment Fixture
Thermal Twang	Sudden thermal bending which the booms experience in passing from a region of total eclipse into a region of continuous sunlight or vice versa
TR	Torsional restraint
TVCS	TV Camera Subsystem